THE INSTITUTION OF PRODUCTION ENGINEERS JOURNAL

JANUARY

THE INSTITUTION OF

PRODUCTION ENGINEERS JOURNAL

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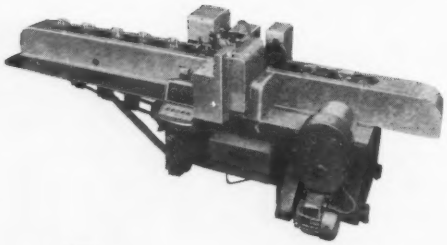

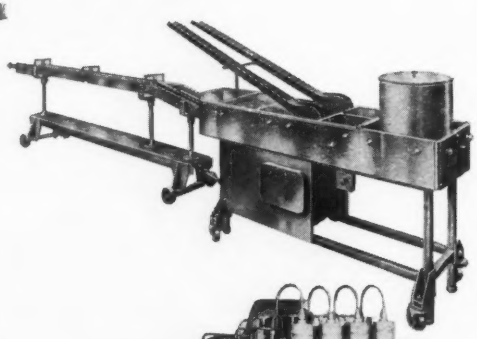

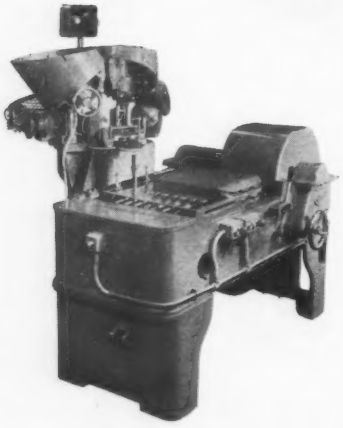

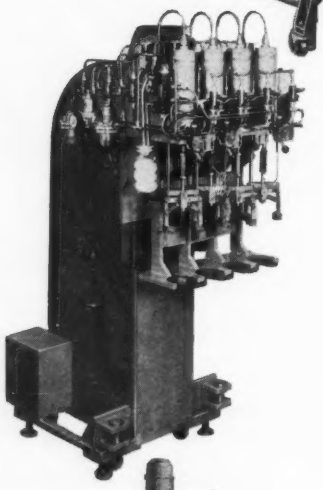

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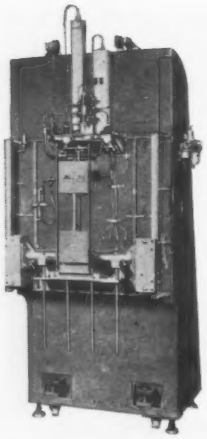

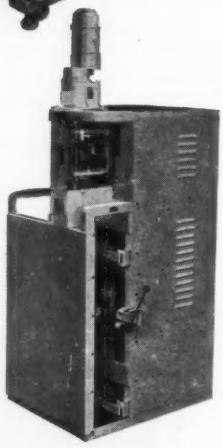

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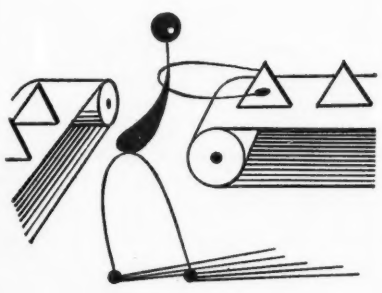

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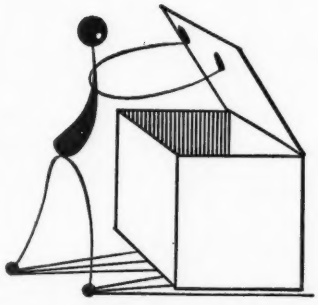

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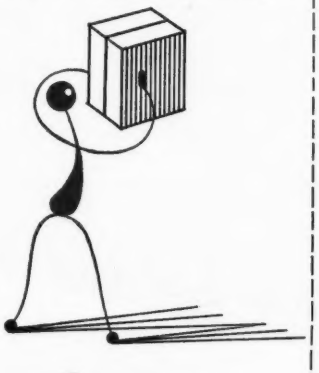
...bend...



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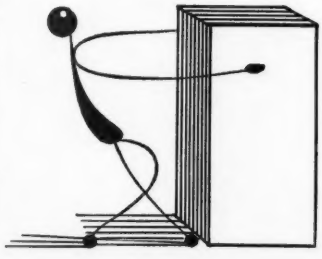

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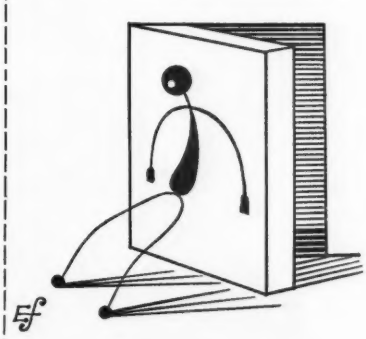

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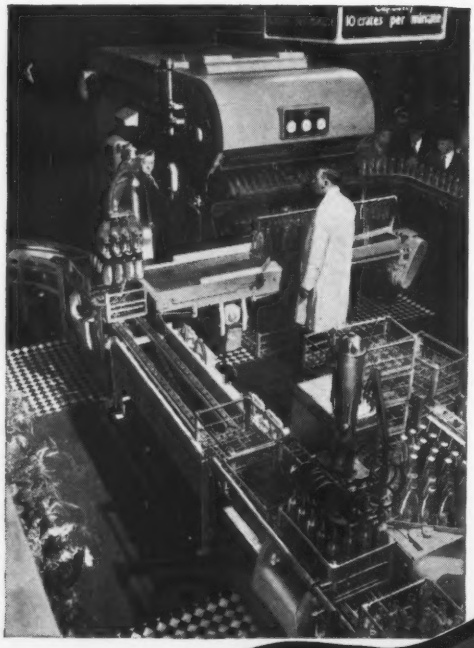

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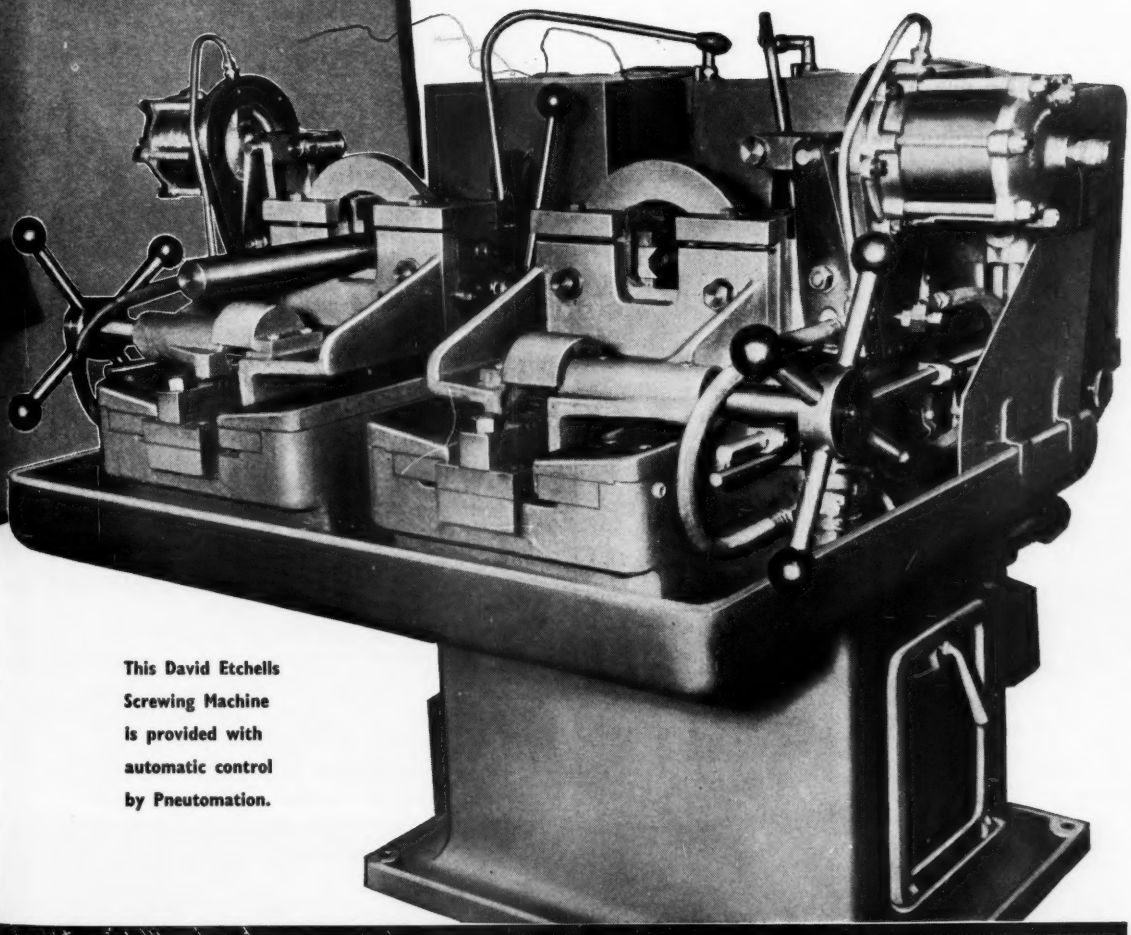

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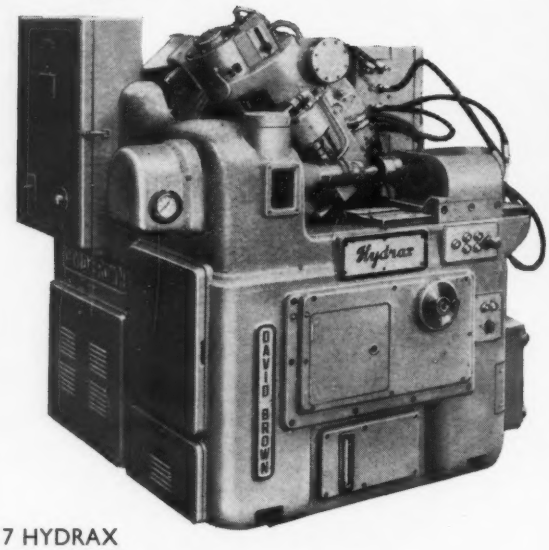
DAVID BROWN

GEAR QUIZ ②

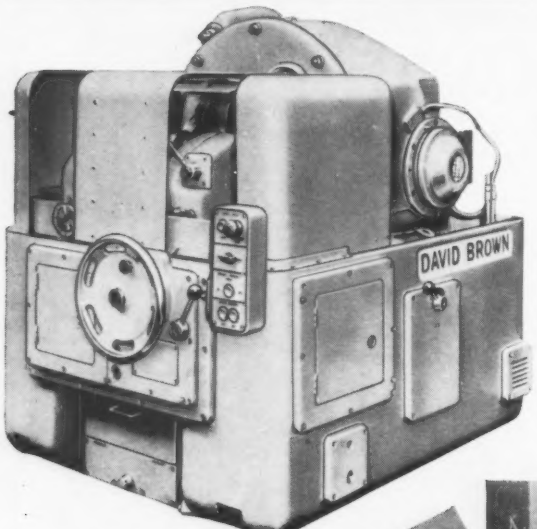
Q *Our Inspection Department insists on a tolerance of ±0·0002 in. per inch of facewidth on helix for gears to be shaved. Can this be maintained on the No. 7 Hydrax machine?*

A **Simplicity itself, as the exact helix angle is set directly on the angular hob traverse scale. Furthermore, any possibility of helix angle variation due to wear is eliminated as the No. 7 Hydrax operates without differential, spiralling gears or lead screw.**

WRITE **NOW** *FOR LEAFLET M 104.4*



NO. 7 HYDRAX
GEAR HOBBING
MACHINE

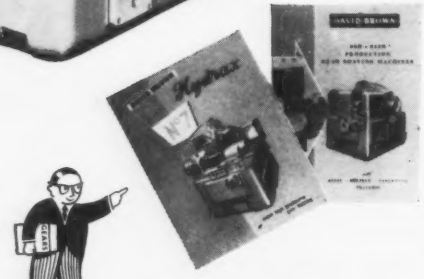


S 6 H
GEAR SHAVING
MACHINE

Q *We already know that the S6H Gear Shaving Machine meets our requirements for standard spur and helical gears. Will it also shave our shoulder gears?*

A **This machine will accommodate all types of gears as three different shaving techniques can be used. These are AXIAL TRAVERSE and OBLIQUE TRAVERSE for standard gears and TANGENTIAL TRAVERSE for shoulder gears.**

WRITE **NOW** *FOR LEAFLET M 103.9*



Ease of loading is a feature of both machines as gears are mounted horizontally at waist height. Both can be arranged for automatic loading with repeat cycle operation and leaflet M105.3 gives details of equipment available.

Please address your replies to Gear Quiz.

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Hylite 20 TITANIUM ALLOY. 5% Aluminium, 2½% Tin Alloy. An alpha alloy of moderate strength. Being readily weldable and easily formed is suitable for sheet metal work where higher strength than Hylite 10 is required.	5% Al., 2½% Sn.	46.0	56.0	18.0	270
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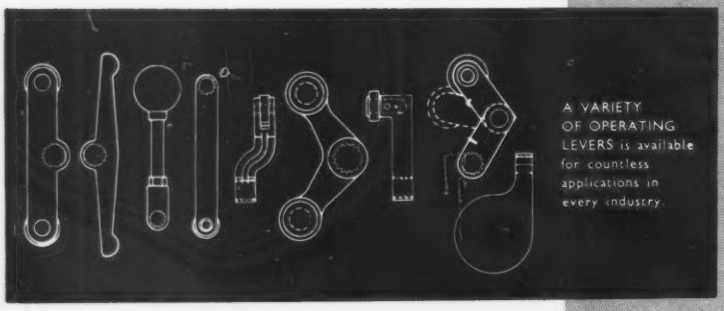

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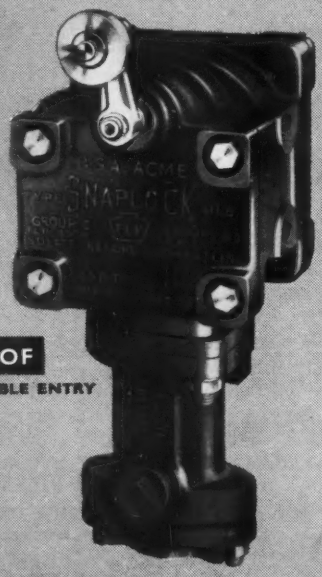

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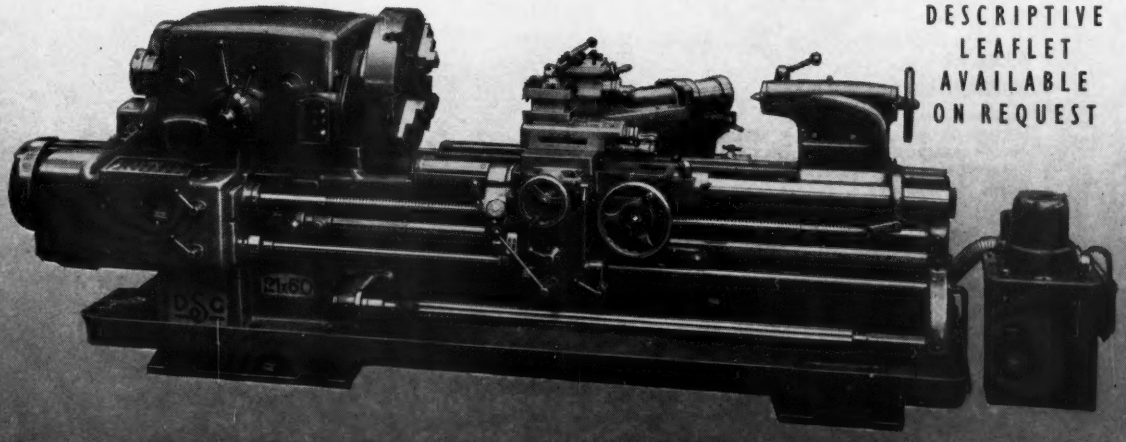

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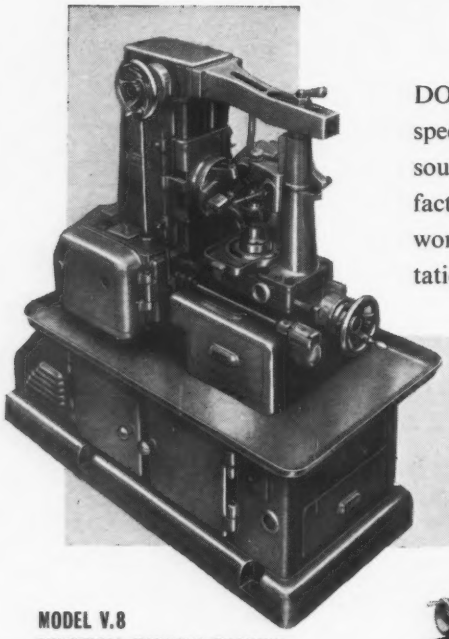

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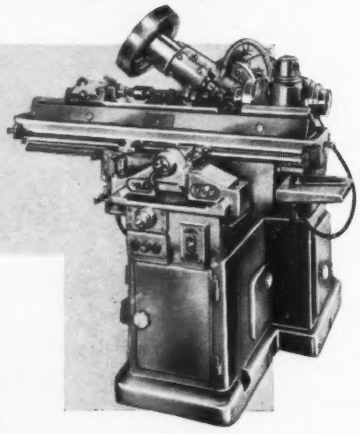

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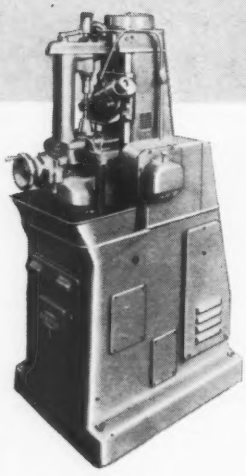

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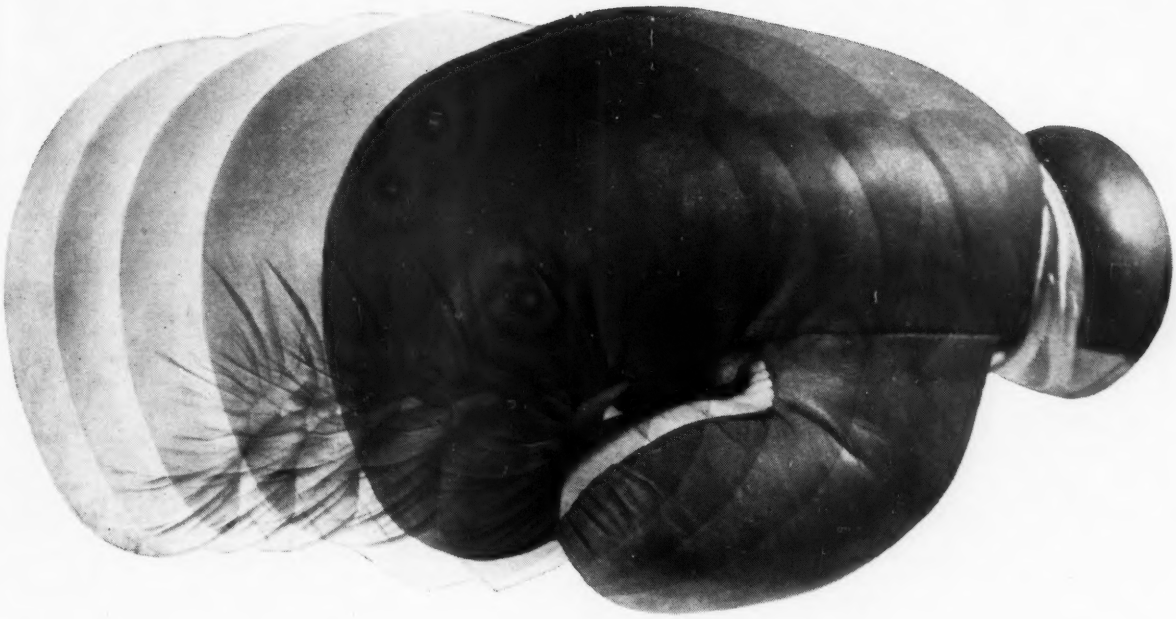

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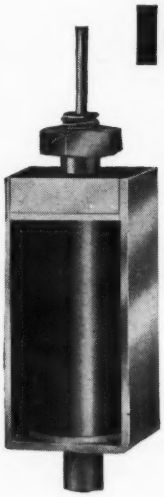

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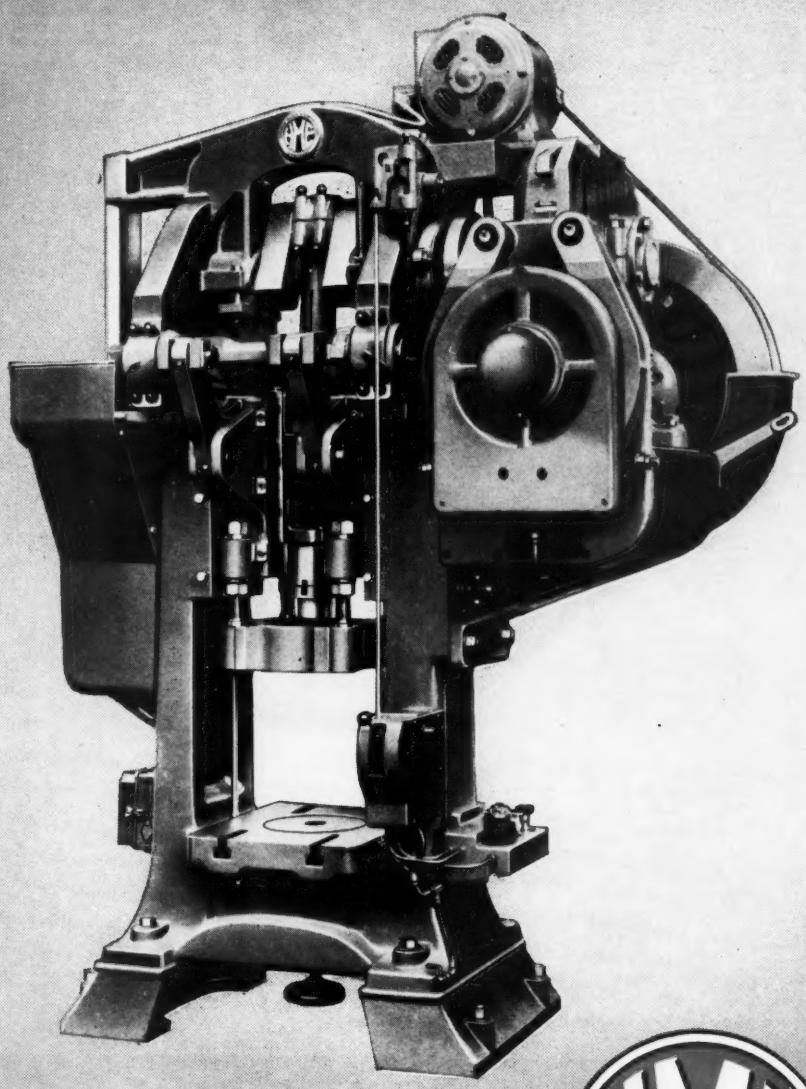

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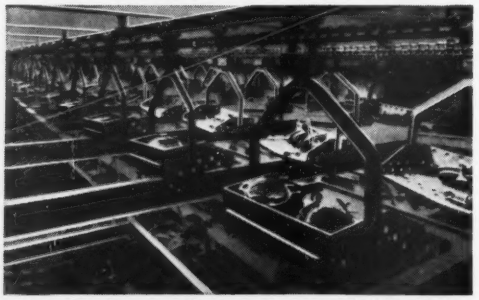
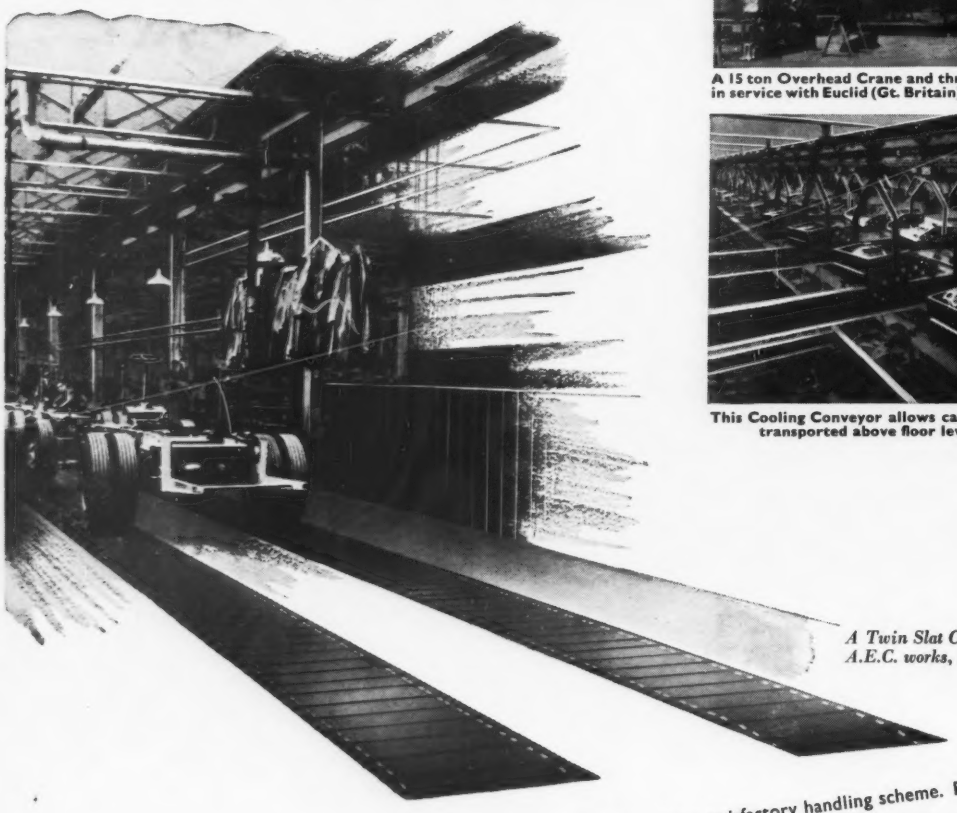


This Cooling Conveyor allows castings to cool while they are transported above floor level to the fettling shop



A Twin Slat Conveyor in operation at the A.E.C. works, Southall, Middlesex

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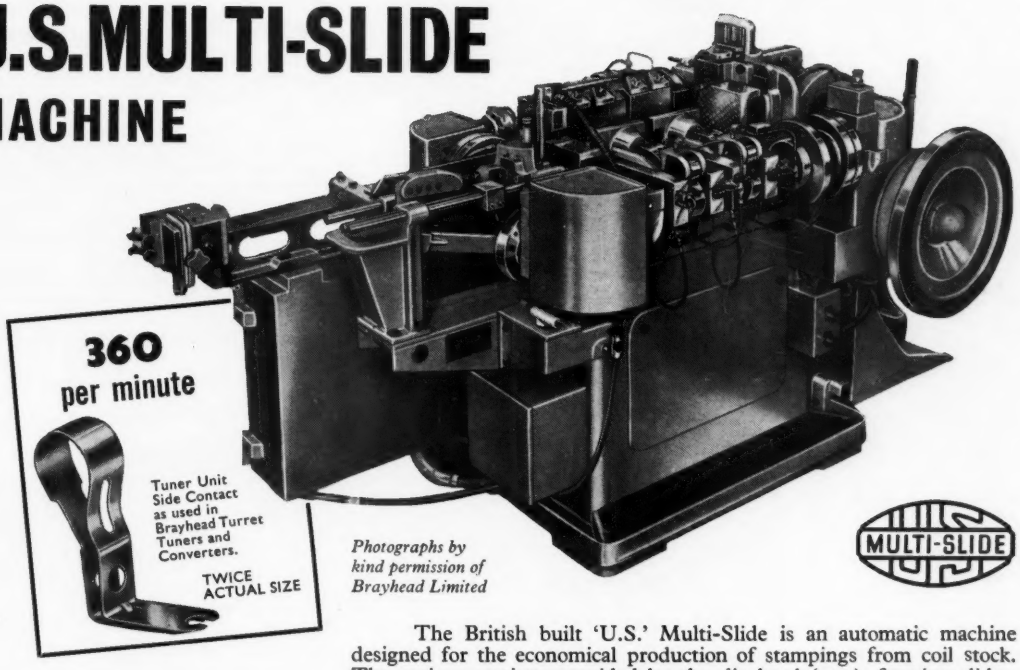

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The British built 'U.S.' Multi-Slide is an automatic machine designed for the economical production of stampings from coil stock. The various motions provided by the die head (ram), forming slides, vertical stripper mechanism and a range of auxiliary units afford the die designer practically unlimited possibilities for the development of tools to produce stampings at considerably lower piece part cost by eliminating secondary operations and handlings.

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Send for illustrated leaflets, also ask to see film showing operation of the machine and examples of components produced. Our Sales Engineer will be pleased to call on request.

Brief Specifications

Machine Model	28	35
Length of Feed	8″	12½″
Maximum Width of Stock	1½″	3″
Maximum Thickness of Stock	1/16″	3/32″

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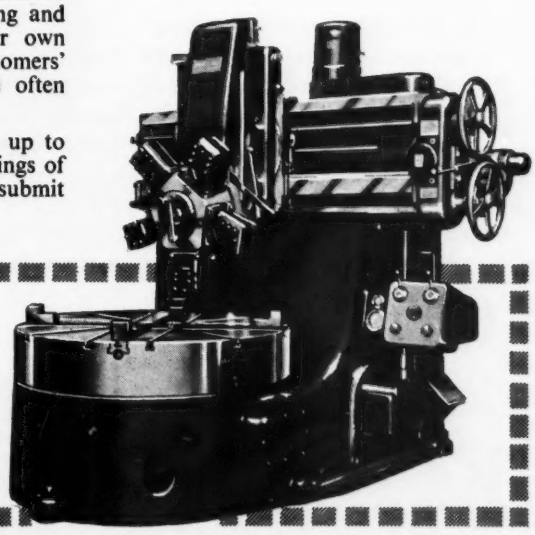

A standard Webster and Bennett Boring Mill with 60″ Chuck, admitting 35″ under the turret and 24″ under the cross-slide

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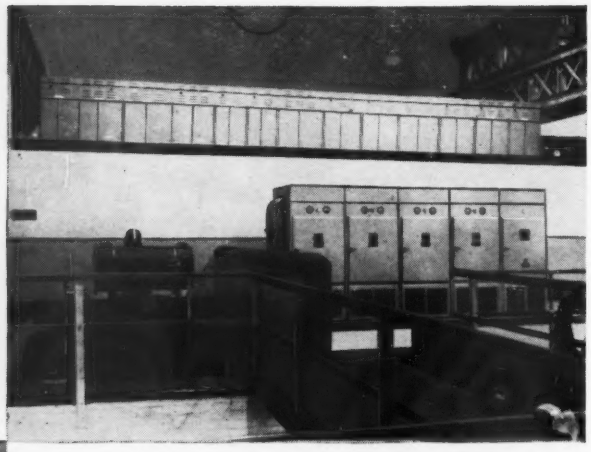

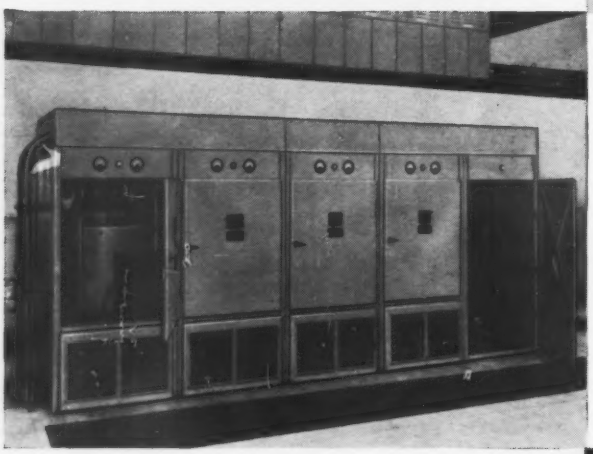

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At the Ebbw Vale steelworks of Richard Thomas and Baldwins Ltd., steelworks auxiliaries are supplied from a Metropolitan-Vickers rectifier equipment rated at 1,000 kW 236 Volts D.C. A rectifier transformer feeds four air-cooled, pumpless steel-tank rectifiers of the Metropolitan-Vickers truck mounted, cubicle-enclosed design. Included in the equipment is an automatic high speed regenerative loading control cubicle of the electronically controlled ignitron type. The cubicle of the ignitron equipment matches those of the rectifiers.

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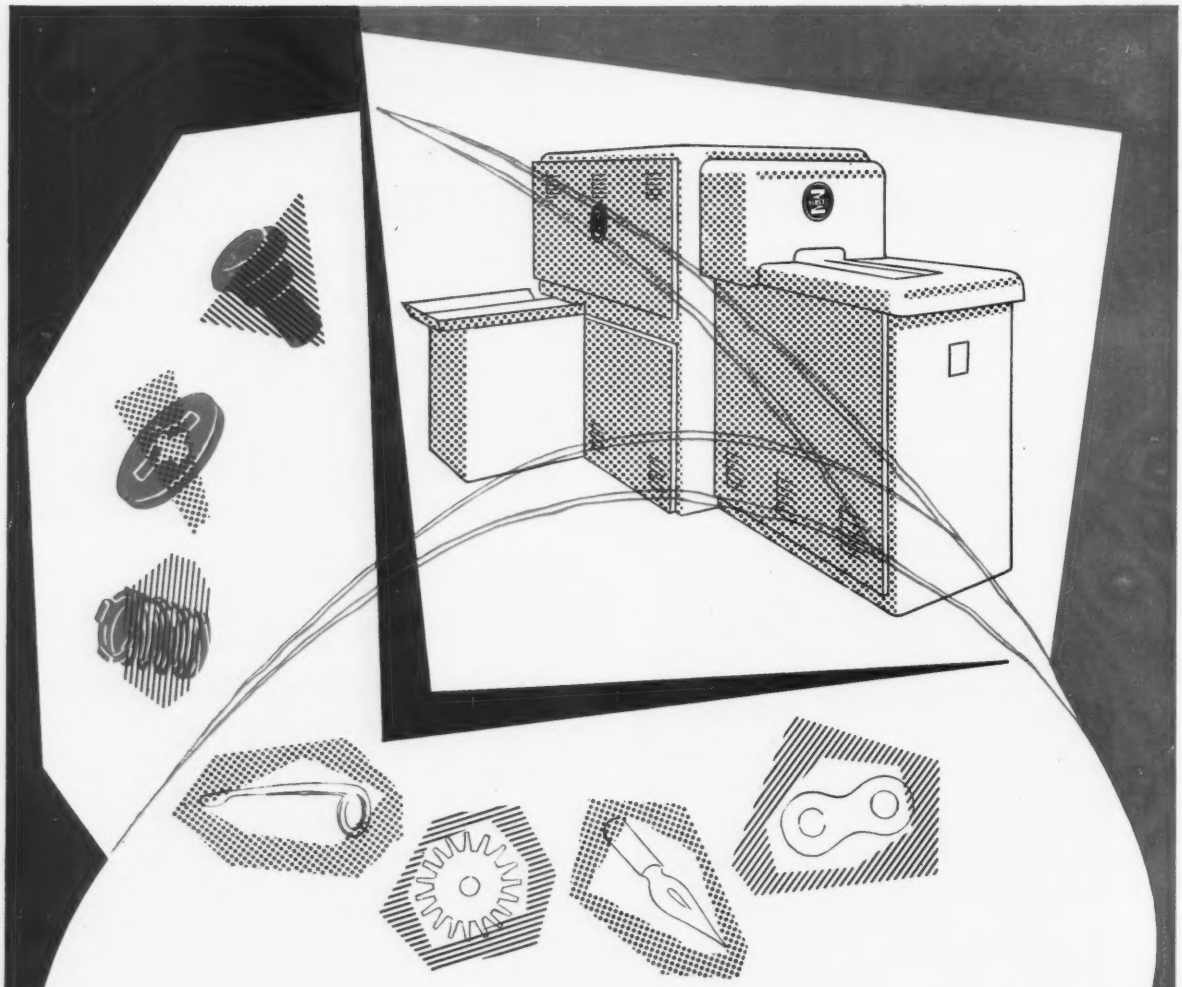

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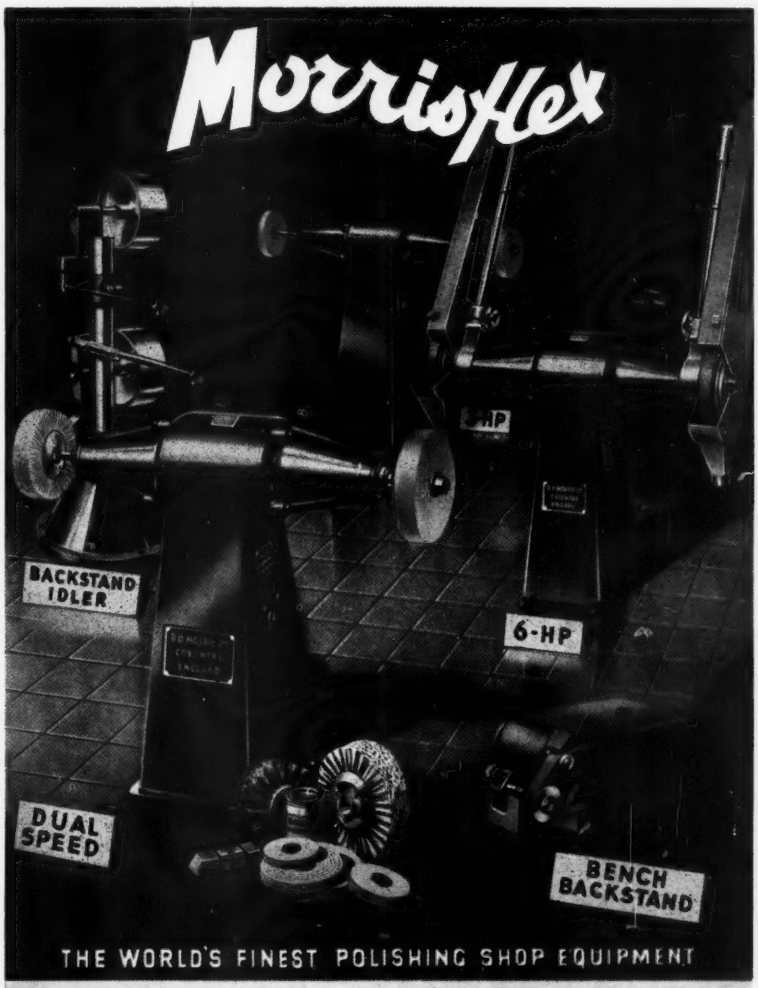

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Our universities do not lack plans to improve relations between industry and undergraduates said Professor P. V. Danckwerts in his inaugural lecture at The Imperial College of Science and Technology. This lecture is substantially reprinted in TECHNOLOGY.

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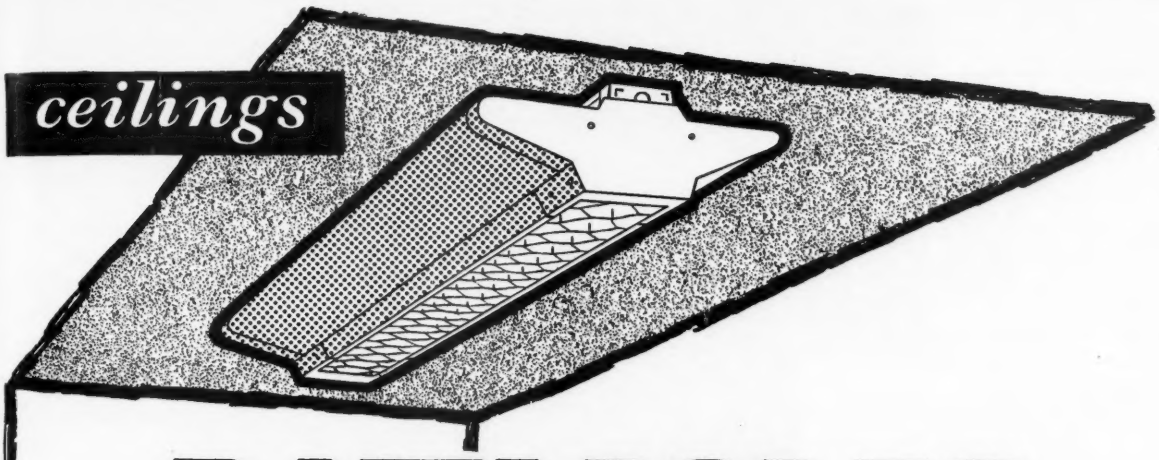

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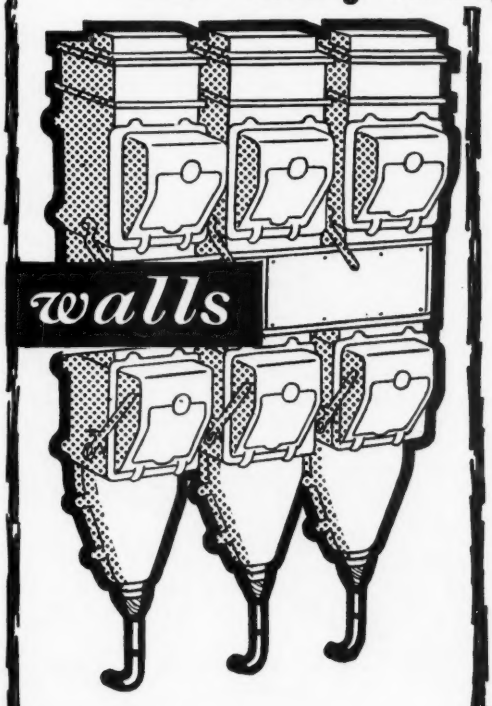

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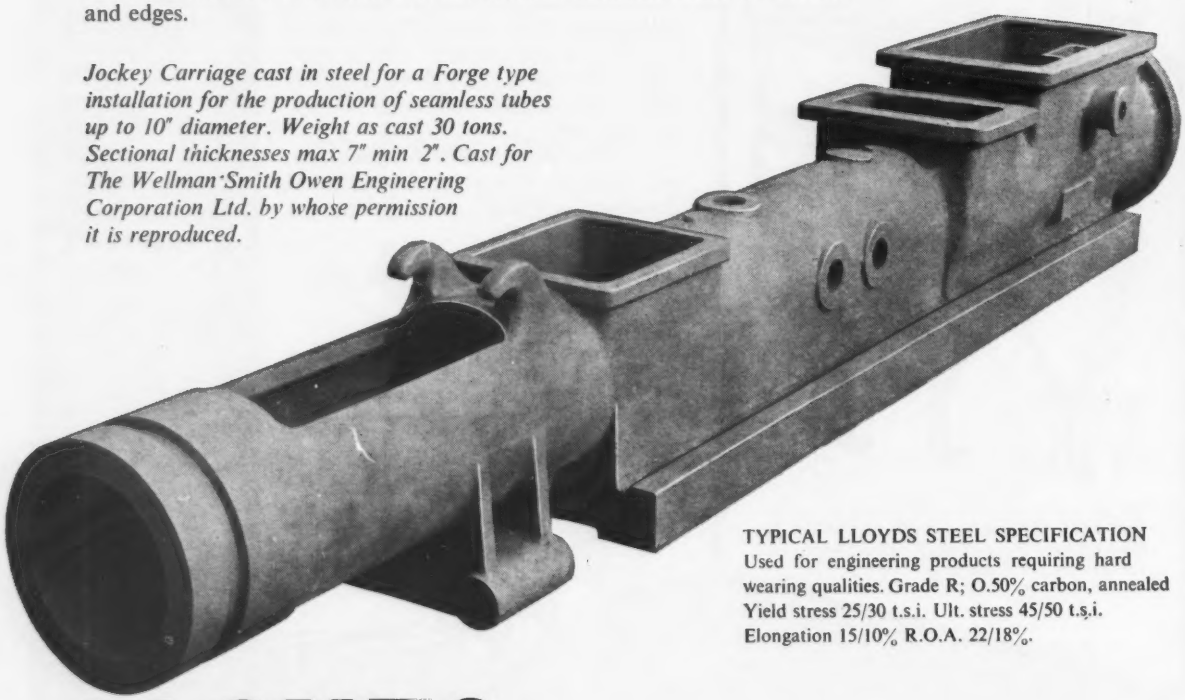
cast for a "shockable" part

This jockey carriage is cast in steel for a forge type of installation for the production of seamless tubes up to 10" diameter, and has to withstand unpredictable shock load. It is a good example of the versatility of steel casting, in that its sectional thickness varies from 2" to 7", essential requirements that make it almost impossible to fabricate by any other method.
Owing to good method planning this casting is free from defects and of especial interest is the fine finish. Note also the sectional thickness round the corners and edges.

Jockey Carriage cast in steel for a Forge type installation for the production of seamless tubes up to 10" diameter. Weight as cast 30 tons. Sectional thicknesses max 7" min 2". Cast for The Wellman·Smith Owen Engineering Corporation Ltd. by whose permission it is reproduced.



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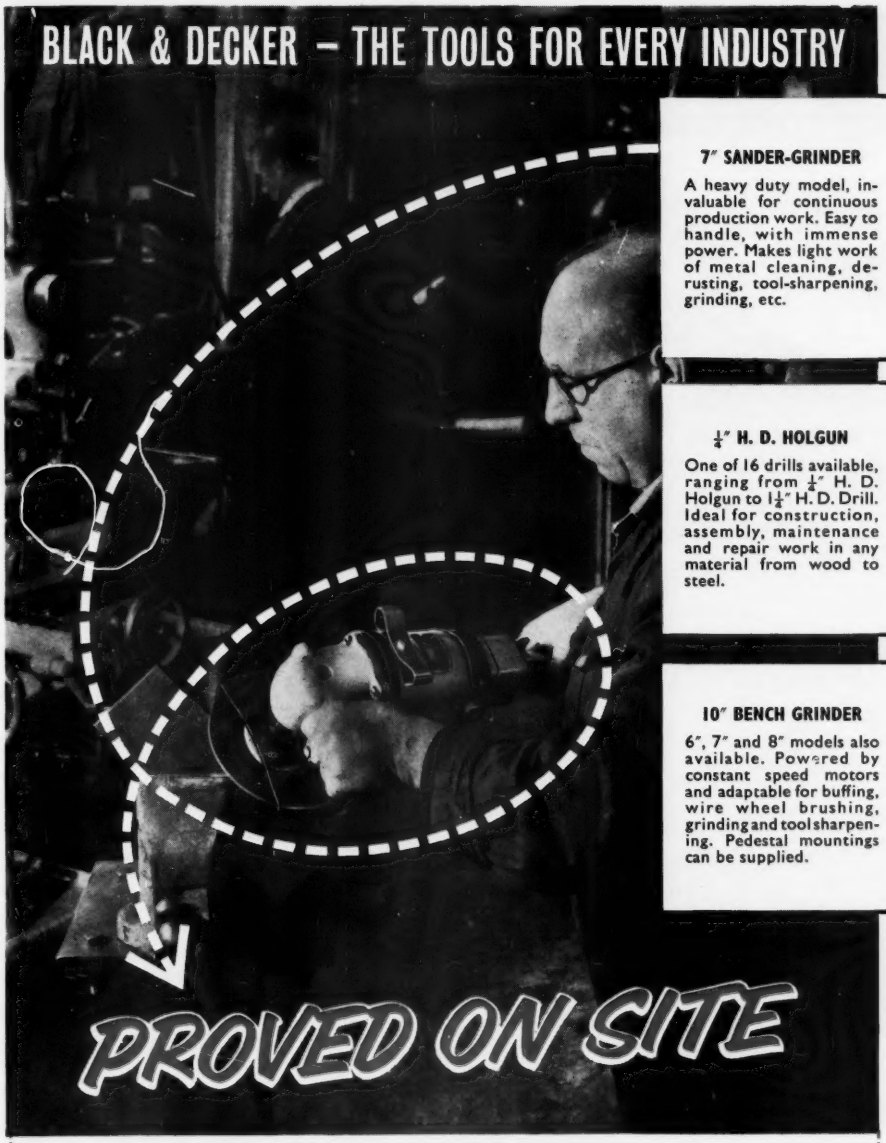

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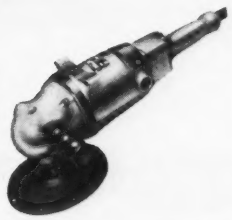

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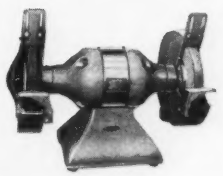

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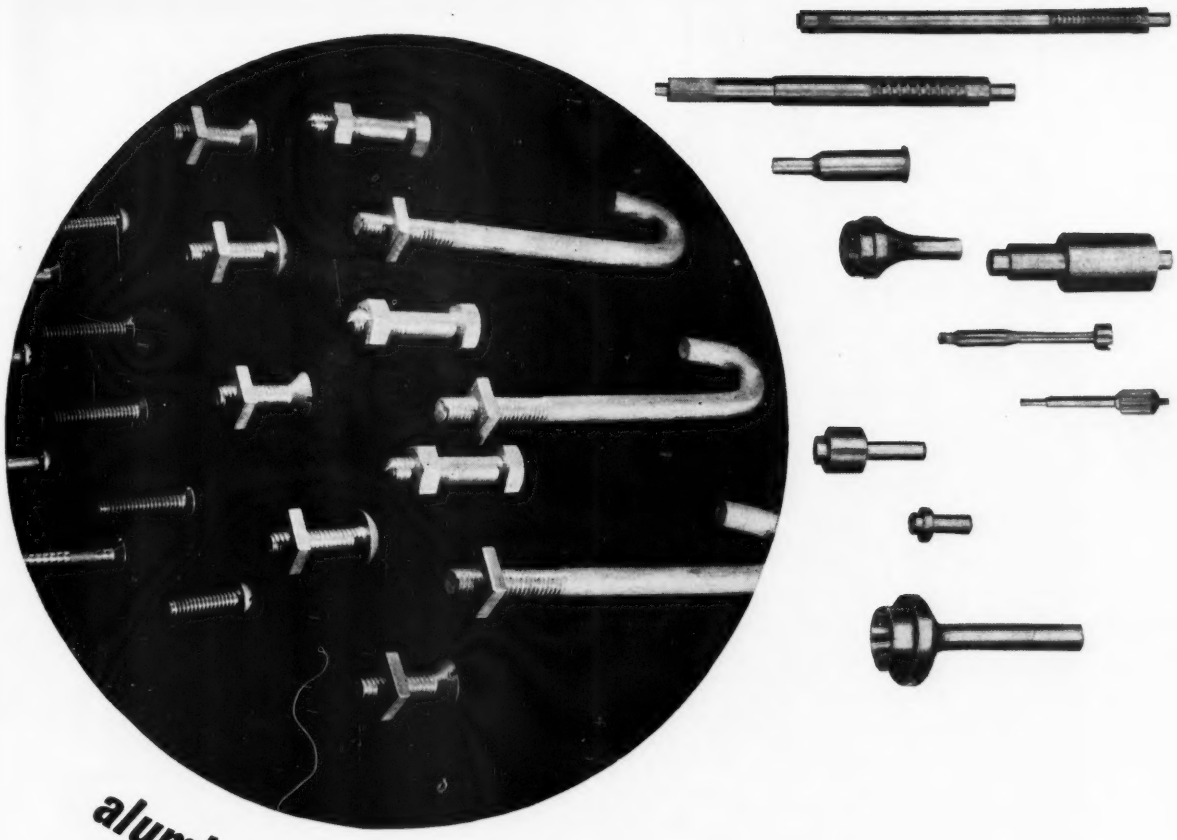
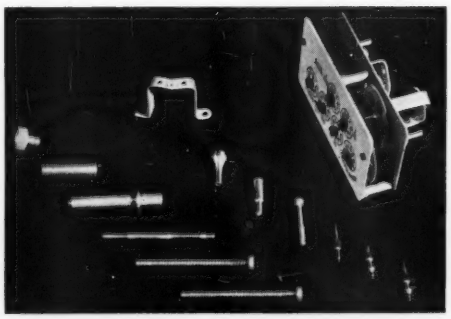


aluminium alloy rod & wire for machining



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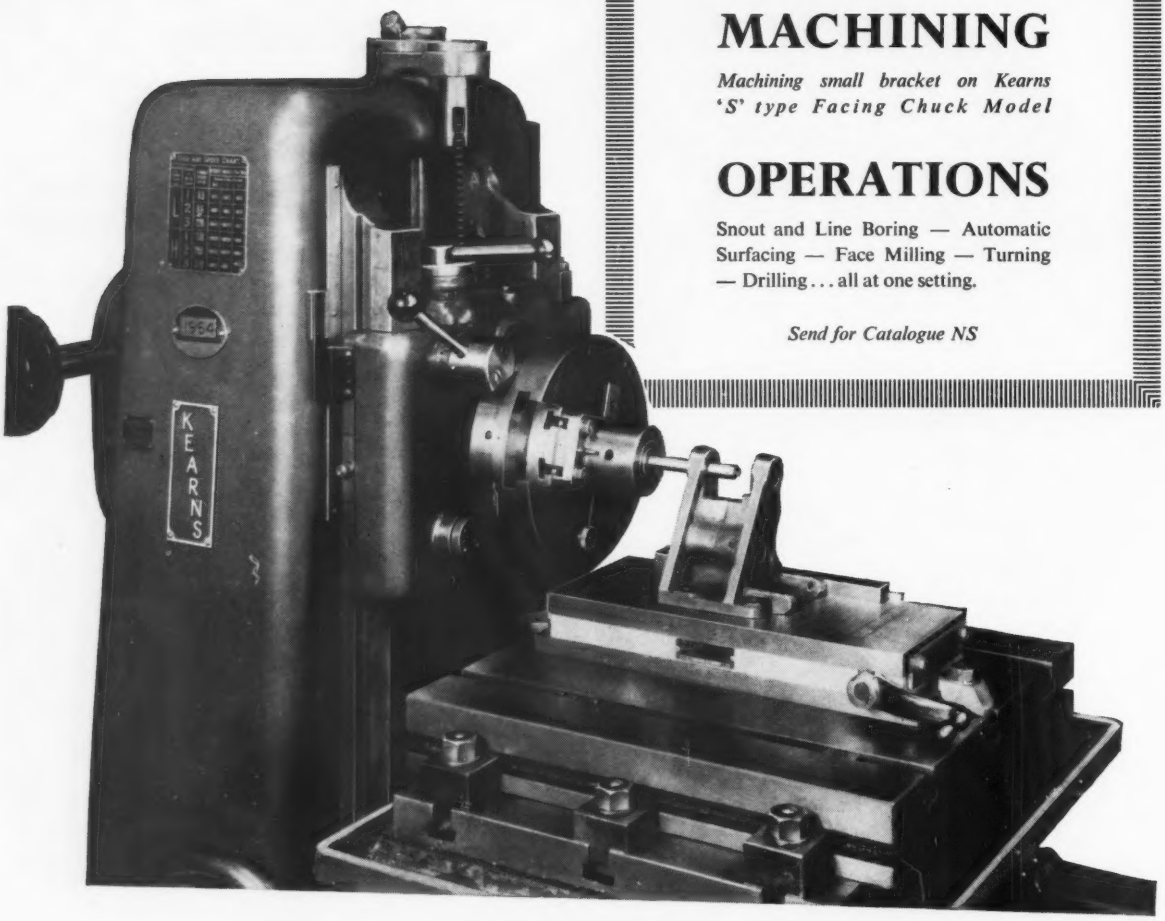

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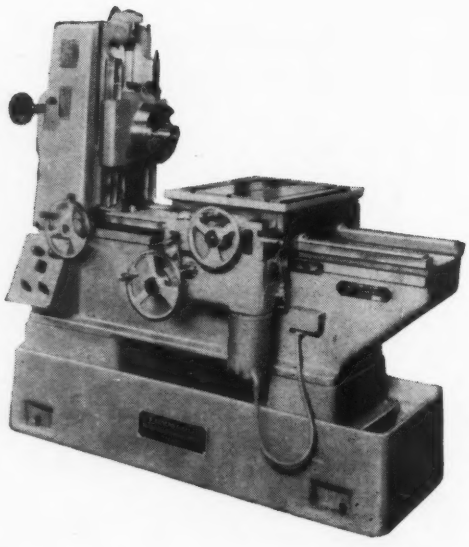

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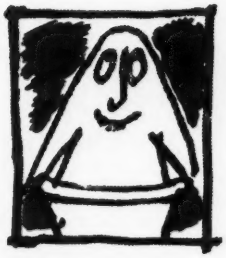
I'm thinking . . .

says Max Am



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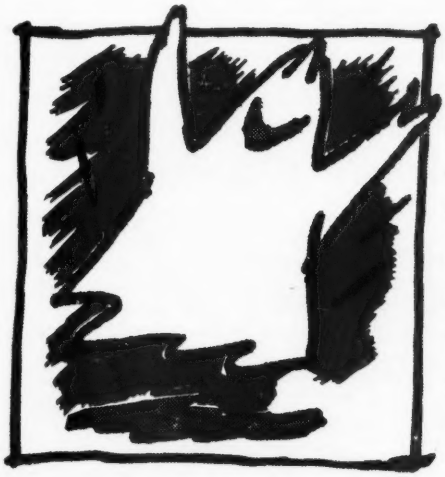

If you have a job, a process, a sequence which you suspect is not as efficient as it could be, the wisest thing you could do would be to write for the help of Max Am. Especially if it is a problem which has defied all previous attempts at solution.

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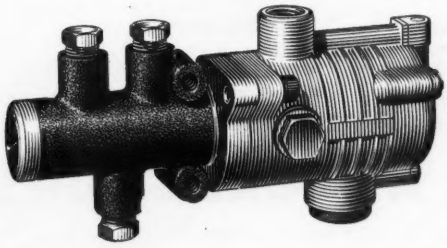

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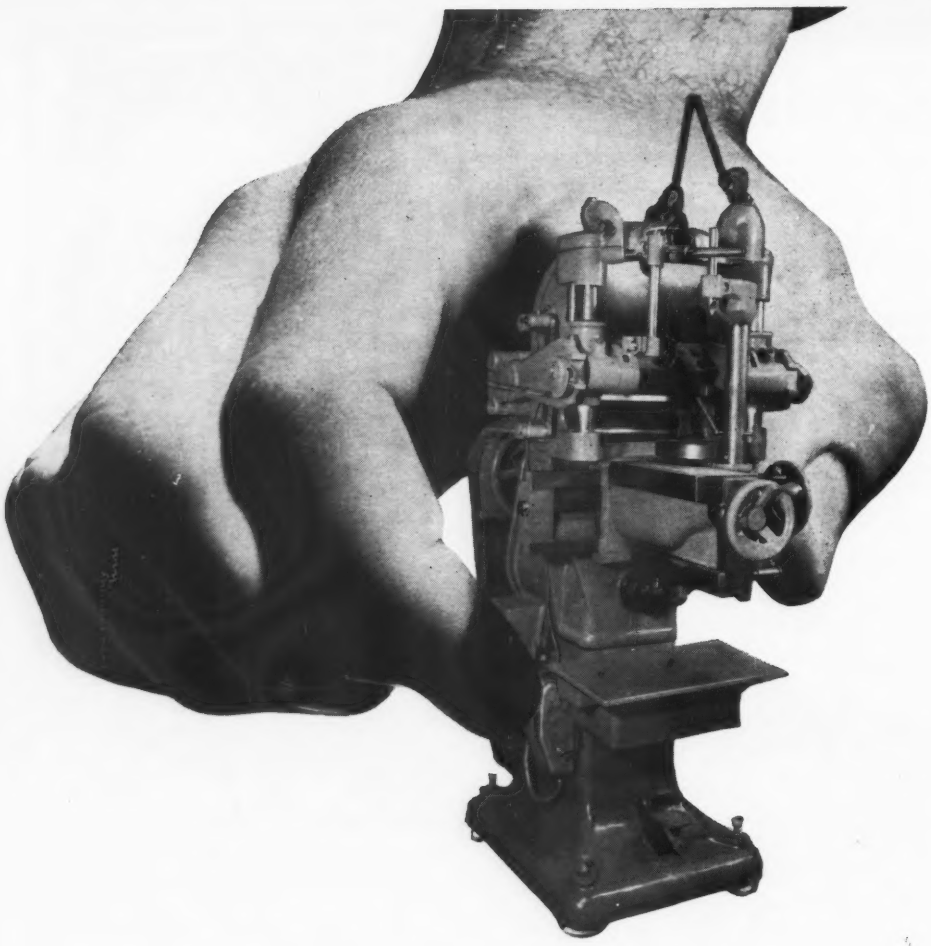

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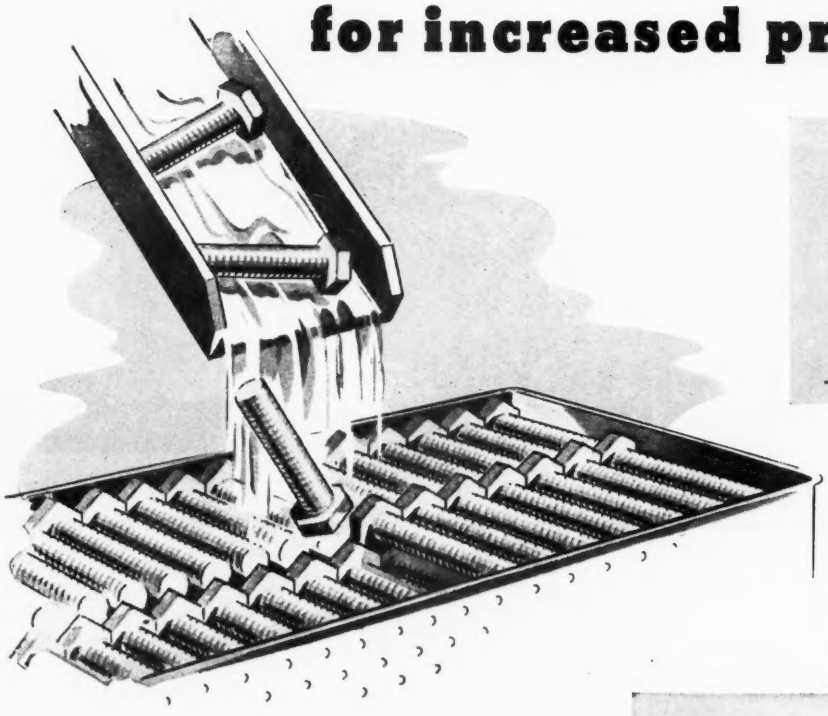

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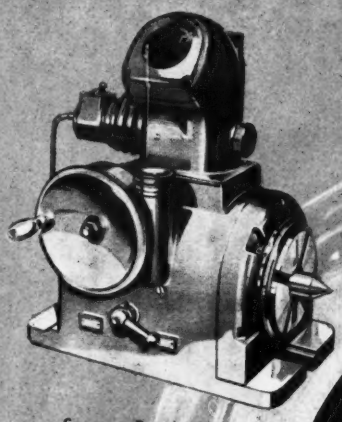

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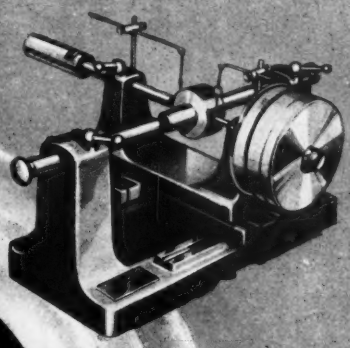

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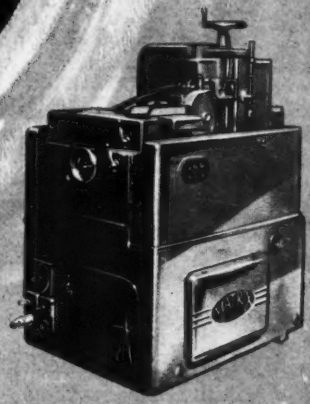

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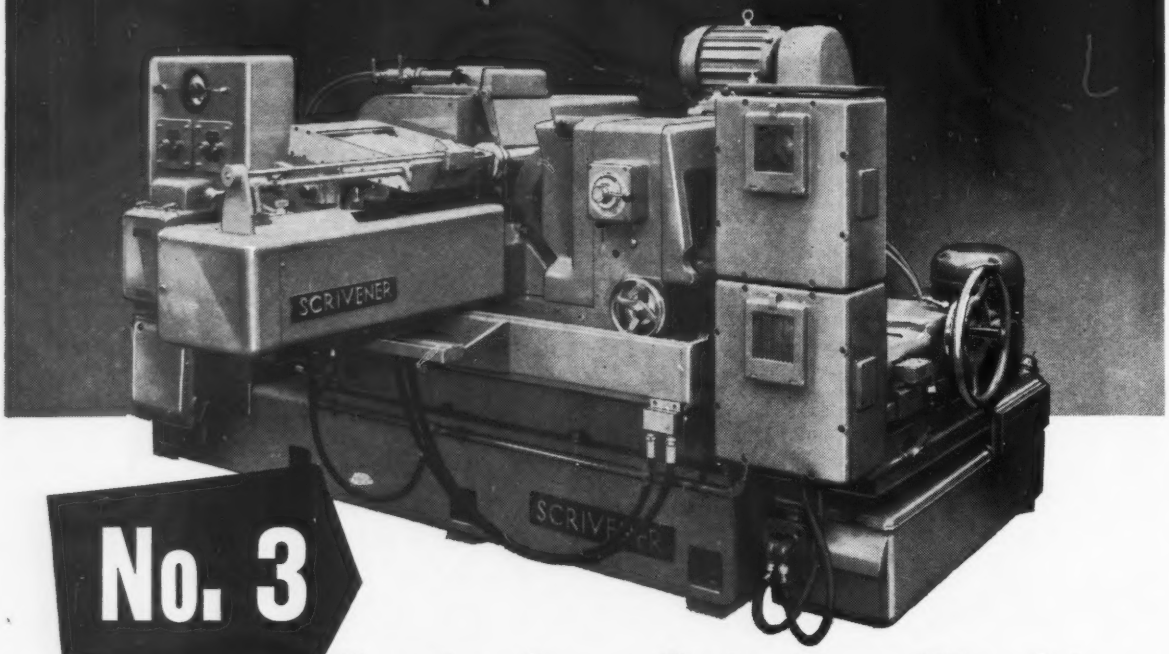

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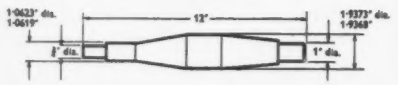

Stub Axle. Plunge grinding two dia. (±0.0002") and two tapers (to gauge) magazine feed.

Total time. 30 seconds. 120 pieces per hour. Stock removed 0.012" to 0.015" in two passes.

The largest machine in the Scrivener range, this new Centreless Grinding Machine was introduced at the International Machine Tool Exhibition, and received wide approbation.

Employing the Scrivener system of controlled cycle operation, it demonstrated the plunge grinding of a stub axle in a total cycle time of 30 seconds (for two operations).

Scrivener machines incorporate, in addition to features for straight-through or hand-operated plunge grinding, a system for semi- or fully-automatic controlled cycle operation. By adopting the latter method, very economical mass production rates can be achieved, the machines feed, grind and eject in sequence and can be incorporated into automatic production lines.

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Model	No. 1D	No. 2	No. 3
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Max. opening between new wheels...	2½" *2"	6" *4½"	9" *9"

*Machines with controlled cycle operation.

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The Institution of Production Engineers Journal
VOL. 37 No. 1 JANUARY, 1958

New Year Thoughts

by The Rt. Hon. The Earl of Halsbury,
F.R.I.C., F.Inst.P., M.I.Prod.E.,
President of the Institution.

TO many, the opening New Year will appear but the latest of a grim series. Like some early cinema comedian who, after slipping on a piece of banana skin, staggers along the side-walk from one position of disequilibrium to another, the world lurches along, apparently unable to achieve stability in its course. What will posterity record of the years that are past ? What must we anticipate of the years to come ? Human memory is continuous back to about six years of age. Children six years old in 1914 will enter their second half-century during the 12 months to come. Those likely to be the leaders of affairs in the next two decades are mostly discernible against the background of the rank and file. What sort of outlook is theirs ? On what historical events is it based ? War and unemployment; slump and unemployment; full employment, rearmament and war. Peace and the atom bomb; cold war and the hydrogen bomb; inter-continental missiles and inter-racial bitterness.

Food for self-pity

Here is food enough for anyone disposed to self-pity. He could well groan and say, " Isn't this where I came in ? ". During the late 1930's we had to live under the shadow of Goering and the Luftwaffe. Now it is inter-continental missiles. During the same period we had to endure the bragging and boasting of Ribbentrop. The same bragging and boasting in the old shrill offensive key now reaches us from further east. For those bred to any standard of intellectual integrity the never-ending double-talk and double-think, the wearisome dialect in which our tragedy appears to be written, are as revolting as they always were. Some no doubt will wish that they lived in another age of the world. So do many who live to see such times, but it is not our concern to be sorry for ourselves or to wish that life were otherwise. Such is the world into which we have been born, and we have to cope with it as it is and not as we would like it to be. Much tragedy lies in the past; more may lie in the future. But if one of the qualities which men are expected to show before the face of the cosmos is courage, then the disasters of the world must be no mere play-acting. The downfall of the innocent and virtuous may be horrifying in its reality. It is the price paid whereby courage is endowed with that same real quality. We live in a great climacteric of the cosmic drama now being played out on this tiny planet. It could be that the curtain is due to fall quite soon. If so, it behoves us not to collapse into self-pity, but to meet our destiny with courage and dignity, whatever it may be.

Social experiment

What else can we discern to comment on ? Where is the bright within the dark ? Amidst the cruelties of the concentration camp, genocide, and the enforced migration of peoples from home to home we see in the West a group of social experiments, each of which has some right to consider itself as the embodiment of a welfare state. Each of them is the most rational attempt that history yet records to terminate the long tale of man's inhumanity to man; each represents an effort to rationalise men's condition of life more deliberate than anything that has happened since the Roman Empire under the Antonines set itself out to humanise the treatment of slaves and to give statutory form to man's duty to his neighbour.

Not all may bless the welfare state, but few will curse it. At worst it represents unease to those raised to think of human activity in terms of an earlier pattern. Like any new institution it produces its absurdities and discomforts, and it is easier to comment upon the stresses which it produces rather than those which it has relieved. The unregulated competition between capital and labour for the same annual increase in the national product is one of them, together with the inflation it produces. Seen in perspective, however, it is a dispute about a half of one per cent. at most and should resolve itself, given good will. Whether we like it or not, however, it is our welfare state and our liberal tradition that are at hazard in the battle of the future.

Let us look at another bright side of the picture. Not each of us has to bear the whole weight of the world upon his shoulders. We live in a democracy where every citizen has a fair share in the appointment of those who carry burdens heavier than the average. We can be sure that if the nation's representatives were not willing to carry that load they would not submit themselves for election. Let them carry it accordingly. Not each of us has to worry about the issues which concern the Prime Minister of the day, whoever he may be. Not each of us is simultaneously Foreign Secretary, Chancellor of the Exchequer and Governor of the Bank of England; those who hold these posts bear the anxieties of their positions. Let us leave them to do so.

Tackling the problems

Those who read this Journal are production engineers, and if they will resolutely tackle their own problems, they will be doing their duty, making their contribution to the country's needs and, if they do it well, will be able to retire in due course with the satisfaction of knowing it well done.

When the martial quality of "Onward, Christian soldiers" was pointed out by a critic to the founder of the Salvation Army, General Booth replied: "Why should the Devil have all the good tunes?". We might well look at our own record and ask, "Why should financiers, accountants and trade unionists have a monopoly of pressure-group tactics? The picture of an engineer under pressure from an accountant is a familiar one. Why don't we hit back? When some drastic reconstruction of methods of production is held up because it is said that the requisite money is lacking, do we resolutely round on the accountant and the financier and tell them that a financier without money is as pathetic as a sick doctor or a politician without a policy? That he is in the ludicrous position of a man who is accorded honours by the community for the theoretical possession of the one faculty that he lacks? When we are told that the financial position is difficult, do we round on the financiers and tell them that if it was easy the office boy could do their work? When labour and capital are competing for their controversial half per cent., do we with a like energy publicise the issues in jeopardy?

Giving a lead

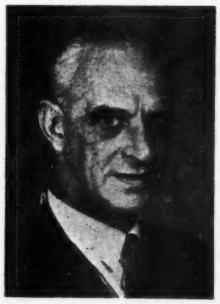
It is often said that the industries of this country are too content with the philosophy of "make do and mend". Do we, as production engineers, ever give a real lead to the nation when it comes to correcting this failing? If not, then we are not doing what ought to be expected of us. Many years ago a large firm in Birmingham looked into the crystal ball and saw itself operating on an over-crowded site, hemmed in by municipal restrictions and too congested with the day's business to set about the reconstruction of the works. Its production engineers, its planners, its finance committee all thereupon set to work on a long-term plan to move the entire establishment out into a satellite district; lock, stock and barrel. Notwithstanding the stresses of war, inflationary collapse in the purchasing power of their reserves, and the difficulties of housing operatives displaced from one district to another, they nonetheless achieved their dream after 20 years of struggle. How many of us have a dream of what the perfect factory might be and to effect it are prepared to struggle for 20 years against the capacity for mischief of the dull? How many of us have acquiesced in patching the unpatchable, with the result that so much cumulative expenditure gets invested in a botched job that it can never be economically written off? If we are tempted to curse the accountant,

(*concluded on page* 50)

The Bases of Measurement

by H. Barrell, D.Sc., A.R.C.S., D.I.C., F.Inst.P.

Presented to the Institution in London, 31st October, 1957.



Dr. Barrell was educated at the Royal Grammar School, High Wycombe, and the Imperial College of Science and Technology (Royal College of Science) London, where he studied physics and later specialised in spectroscopy. He joined the staff of the National Physical Laboratory in 1923, *and was later associated with Mr. J. E. Sears, then Superintendent of the Metrology Division, in determinations of the yard and the metre in wavelengths of light, and of the refractive index and dispersion of air.*

Dr. Barrell also developed the prototype model of the NPL gauge interferometer for the direct evaluation of slip and block gauges to an accuracy of one-millionth of an inch. In 1939, *he transferred to engineering metrology and later became responsible for establishing NPL Testing Stations and gauge stores in various works of a large manufacturer of gauges for the Ministry of Supply.*

He returned to Teddington in 1943, *and took charge of development work on pneumatic gauging, adapting this principle in machines for the simultaneous inspection of several dimensions on certain types of ammunition and for rapidly measuring the thickness of mica sheets. After the War, he was in charge of research in the Metrology Division concerned with optical and microwave interferometry, directed towards improving the precision of length measurements, and published several Papers on the subject of the wavelength standard of length.*

Dr. Barrell succeeded Dr. F. H. Rolt as Superintendent of the NPL Metrology Division in 1953. *He is the member for the U.K. on the International Committee of Weights and Measures, and the NPL representative on this Committee's advisory body on the definition of the metre.*

LORD Kelvin [1] once remarked in a lecture: "I often say that when you can measure what you are speaking about and express it in numbers you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind." This aphorism of one of our most illustrious scientists of the 19th century states a general truth inherent in all those human activities especially concerned with the acquisition of scientific knowledge, of which he was speaking, and equally with the applications of such knowledge for the advancement of our economic welfare. It will certainly not be denied that production engineering is one activity in which measurement is a basic ingredient of progress.

To reduce the process of measurement to its simplest terms, let us consider what we do when asked to measure, say to the nearest tenth of an inch, the length of a straight line drawn on a sheet of paper. We take, let us suppose, a 12-inch scale, divided into inches and tenths of an inch, which we lay with its divided edge along the line, setting the zero of the scale for convenience into coincidence with one end of the line. We then obtain the length of the line by observing where the other end of the line falls along the scale and noting on the scale the number of complete inches and the nearest number of excess tenths of an inch contained in the length of the line. In such a process the scale is described as the standard of measurement and its inch divisions represent the unit of measurement. The length of the line has been determined by comparing its length with that of a standard and ascertaining from the standard the whole number of units of length and the excess fraction of a unit contained in the line.

I have risked boring you at the outset with such an elementary example because it brings out so clearly a principle of universal application in

measurement. Measurement always involves some kind of comparison and is usually accomplished by comparing the quantity to be measured with a standard whose value is known in terms of the unit of that quantity, although the presence of the standard in any particular measuring instrument may not perhaps be so easily recognised as it is in instruments described as "comparators". In outlining the process of measurement the terms unit and standard have been introduced, and it is important to distinguish between them. A unit is essentially an abstract conception and cannot be utilised as a practical basis of measurement until it has been defined in one of two ways: either by reference to arbitrary material standards or by reference to natural phenomena, including in the latter physical constants and the properties of specified substances. Both methods are used and, indeed, on occasion, both have been used at different times for the same unit. For example, in the metric system the unit of length is defined by the separation of two lines engraved on a particular bar of platinum-iridium, but I shall presently describe how it is soon likely to become referred to a certain number of wavelengths of a particular radiation of light; the metric unit of mass, once defined as the mass of a certain volume of water, is now specified to be the mass of a particular cylinder of platinum-iridium; and the unit of time, for long defined by reference to the natural phenomenon of the Earth rotating about its axis (or of the Earth revolving about the Sun), may eventually be expressed in terms of the natural periodicity of a certain kind of atom, as in the NPL caesium atomic frequency standard.

Systems of measurement

Theoretically the unit for each different kind of measurable quantity could be fixed quite independently of those for every other kind. But it would obviously be very inconvenient in practice to have a conglomeration of arbitrarily chosen, disconnected units and we therefore try to employ the fewest possible number of independent units, which are then called fundamental or basic, as the foundation of systems of measurement. Such systems can be developed for groups of quantities which are interconnected by means of some physical law. For instance, the second law of motion in Newtonian mechanics, relating the quantities length, mass, time and force, provides a logical basis for the development of comprehensive systems for the mechanical units. If units of any three of these measurable quantities are chosen as fundamental, the unit of the fourth, together with the units of other dynamical quantities, can be derived. Length, mass and time are generally accepted as the three fundamental quantities in systems of scientific and legal measurement. In the metric system the unit of length is the metre, the unit of mass is the kilogram and the unit of time is the second. This system legally coexists in the countries of the British Commonwealth* and in the United States of America with the older system in which the unit of length is the yard, the unit of mass is the pound and the unit of time is again the second.

On the other hand, in the gravitational systems of units commonly used for certain engineering and aerodynamical measurements, length, force and time are fundamental and mass is derived. Thus the metre, the *weight* of the kilogram and the second are the fundamental units in the metric gravitational system; the foot, the *weight* of the pound and the second are the fundamental units of the analogous foot-pound-second system. A disadvantage of the fundamental unit of force as defined by the weight of a given mass is that the standard which represents it varies over the Earth's surface on account of the variations of gravitational acceleration with position and altitude on the Earth.

Scope and organisation of metrology

During the past 70 years many standards laboratories have been set up to undertake, for national purposes, the establishment and maintenance of standards for the whole field of scientific and industrial metrology. This field includes not only the standards of length, mass and time, with their derivatives in the mechanical system, but also the temperature scales, standards for electricity and magnetism, photometric standards, radiological standards and the like. The standards laboratories, of which the NPL is the second oldest, also undertake the associated test and verification work for science and industry. Their activities are co-ordinated with those of the corresponding national standardising authorities, such as the British Standards Institution (BSI) in this country, and of the International Organisation for Standardisation (ISO). The international metric organisation created by the Metric Convention of 1875 also has a central laboratory, the International Bureau of Weights and Measures, at Sèvres (near Paris), with duties analogous to those of the national laboratories but concerned more especially with international co-ordination of all scientific work relating to the maintenance and improvement of the metric system.

In what follows I shall give an account of the fundamental standards of length, mass and time, with notes on their maintenance and improvement, but the emphasis is on standards of length because of their special interest in production engineering. Of the standards for derived quantities in the mechanical system used by the production engineer I have selected for discussion angle, force (or load) and hardness.

Standards of length

Types of material standard: Under carefully specified conditions a standard of length may be represented by the distance between (a) two parallel lines engraved upon a material bar, called a line-standard, or (b) two flat and parallel end-surfaces of

* India introduced the metric system as the legal system of weights and measures in 1956; the change is estimated to take 15 years to complete.

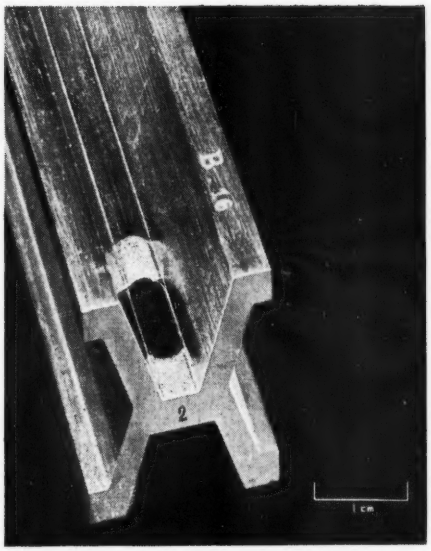


Fig. 1. One end of the British copy (No. 16) of the Metre, showing a pattern of defining lines ruled on a polished facet in the neutral plane of the bar

a material bar, called an end-standard. Both the line-standard and the end-standard have served at different times as the ultimate reference for length in the British system of weights and measures and in the international metric system. The present standards [2] are the Imperial Standard Yard, a bronze line-standard established in 1856, and the International Prototype Metre (see Fig. 1), a line-standard of platinum-iridium (90% platinum, 10% iridium) which, in 1889, replaced the platinum end-standard (the Mètre des Archives) that superseded the original natural standard based, as is well known, on a certain terrestrial dimension. Other materials used for the construction of line-standards and precision scales are nickel, nickel-steel alloys including invar, fused silica and glass. Steel containing 1% carbon is ordinarily used in the stabilised condition as the material for constructing the precision engineer's end-standards, either hardened throughout for lengths up to 4 in. (10 cm) or hardened at the ends only for greater lengths.

The light wave standard : During the development of the wave theory of light J. Babinet suggested, in 1829, that the wavelength of light might serve as a natural standard of length. It was not till 1893, however, when A. A. Michelson and J. R. Benoît made the first direct determination of the metre in wavelengths of the red radiation of cadmium, that the suggestion was shown to be realisable in practice. During 1905 - 1906, J. R. Benoît, C. Fabry and A. Perot repeated the determination, using improved methods and apparatus. Their originally announced value, 1 553 164.13, for the number of wavelengths of cadmium red light contained in the Prototype Metre confirmed the earlier value within the experimental accuracies assigned to the two determinations. In 1927 the General Conference of Weights and Measures (the supreme authority in the international metric organisation) gave formal sanction, as an interim measure, to determinations of length being made by reference to the value, quoted above, of the metre in wavelengths of cadmium red light, as an alternative to use of the Prototype Metre or its authorised copies. Further confirmation of the reproducibility of a wavelength standard has been obtained from the results of seven subsequent determinations of the Prototype Metre, the mean value derived from the nine determinations [3] being 1 553 164.12 wavelengths of cadmium red light in air under specified standard conditions. Of these nine measurements of the Metre, two were accomplished at the NPL during the period 1933 - 1935. During the same period the Standard Yard was also measured at the Laboratory in terms of the same cadmium wavelength, the value obtained being 1 420 210.74 wavelengths; this differed but little from an earlier value, 1 420 209.8 wavelengths, determined in 1931 by A. E. H. Tutton at the Board of Trade Standard Weights and Measures Department.

The interesting conclusion drawn from the wavelength measurements of the Metre is that no evidence

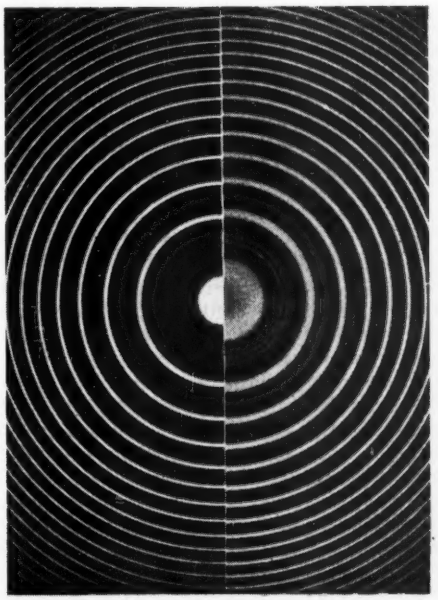


Fig. 2. Comparison photograph of interference fringes in green light of mercury-198 isotope (left) and natural mercury (right)

of any systematic change in the length of the standard is shown, over a period of nearly 50 years, compared with the wavelength of light. Furthermore, the greatest departure of any individual value from the mean is less than 3 parts in 10 millions ((0.3μ in 1 m), an amount very little higher than the uncertainty of 0.25μ considered by experienced metrologists to be associated with the definition of the metre length by means of the Prototype and its authorised copies.

At the ninth General Conference of Weights and Measures (1948), a resolution was adopted recognising the possibility of defining the metre eventually in terms of wavelengths of a radiation from a pure isotope of even atomic mass and charge, such as cadmium-114, krypton-86 or mercury-198. The comparison interferogram, Fig. 2, illustrates the remarkable simplicity of the green radiation of mercury-198 isotope in relation to the complexity of the same radiation of the natural element mercury. In 1953, an international advisory committee on the definition of the metre recommended that a new definition should be based on the wavelength of an isotope radiation propagated *in vacuo* and that continuity with the existing metre unit be preserved through the intermediary of the cadmium red radiation. It was not possible at that date to select the particular radiation to serve as the ultimate standard of length, owing to lack of sufficient comparative experimental data on the characteristics of the various sources and radiations under consideration, but much work on the subject has been done since then in the various standards laboratories. Indeed, when the advisory committee met again last September it was able to make an unanimous recommendation that the metre be defined as equal to 1 650 763.73 times the wavelength *in vacuo* of the orange-red radiation of krypton-86. This definitive recommendation, if accepted by the International Committee of Weights and Measures when it meets in 1958, will be submitted for the approval of the General Conference when it next assembles in 1960.

The yard-metre relationship: The need for an ultimate standard of length based on a stable natural phenomenon is emphasised by the history of the Imperial Standard Yard. This bar and its parliamentary copies are made of a particular kind of bronze known as Baily's metal, and it has long been suspected from indirect evidence that the whole family of standards may have shortened by 0.0002 in. during the early years of its existence. No direct evidence of any progressive changes in the lengths of these standards was brought to light, however, by the statutory decennial comparisons of the standards carried out as required by the Weights and Measures Act of 1878. The realisation that the yard standards were each subject to the same secular instability came from the evidence provided by a series of determinations of the ratio of the imperial and metric standards over the period 1895 - 1947, the results of which are summarised as follows:

Date	*Value of 1 metre expressed in inches*	*Value of 1 inch expressed in mm*
1895	39.370 113	25.399 978
1922	39.370 147	25.399 956
1932	39.370 156	25.399 950
1947	39.370 186	25.399 931

As the Metre has remained constant to within 3 parts in 10 millions with respect to the wavelength of light during roughly the same period, the above results may be taken to indicate that the yard steadily decreased in length by about 2 parts in a million between 1895 and 1947, equivalent to an average rate of about 1 millionth of an inch per annum. The legal yard-metre relationship for purposes of trade is the figure for the year 1895. To establish stability in scientific and industrial measurements of length made in terms of the yard or its customary sub-multiples in the United Kingdom, the lengths of line-standards, scales, standard gauges, geodetic surveying tapes and other measures of precision verified at the NPL are based on the length of the Yard in 1922, using as control the yard-metre ratio then determined, namely, 1 yard = 0.914 398 41 m or 1 m = 39.370 147 in.

The United States Yard: By an Act of Congress, 1866, which legalised use of the metric system in the U.S.A., the United States Yard is described as the ratio 3600/3937 of the metre, i.e., 1 yard (U.S.) = 0.914 401 83 m, 1 m = 39.37 in. (U.S.), 1 in. (U.S.) = 25.400 051 mm, and this ratio is accepted as the definition of the U.S. Yard in the Mendenhall Order of the United States Treasury promulgated in 1893.

An international yard: A proposal to redefine the yard as exactly equal to 0.9144 metre (or 1 in. = 25.4 mm exactly) was put forward by the Royal Society Empire Scientific Conference [4] in 1946. In 1951, the Committee on Weights and Measures Legislation, set up by the Board of Trade under the Chairmanship of Sir Edward Hodgson, recommended in its Report [5] the adoption of this relationship. This was quoted as an alternative to the primary recommendation for complete adoption of the metric system in an obligatory fashion after a change-over period of 20 years. The committee also advised that consultations with the United States be made to assess the possibility of introducing legislation, both in the United States and the British Commonwealth, to fix the value of the yard once and for all in terms of the metre. The adoption of the common definition proposed above would bring into exact agreement the two yards, which at present differ by from 3 to 5 parts in a million according to the basis of conversion used. Such discrepancies are significant to the manufacturers of length standards of the highest qualities.

The comparison of line-standards: Fig. 3 illustrates a classic form of line-standard comparator [6] by means of which visual observations are made through microscopes on the defining lines of the standards; it is that in current use at the NPL for all work on the national and other important standards of length. The standard bars to be compared are

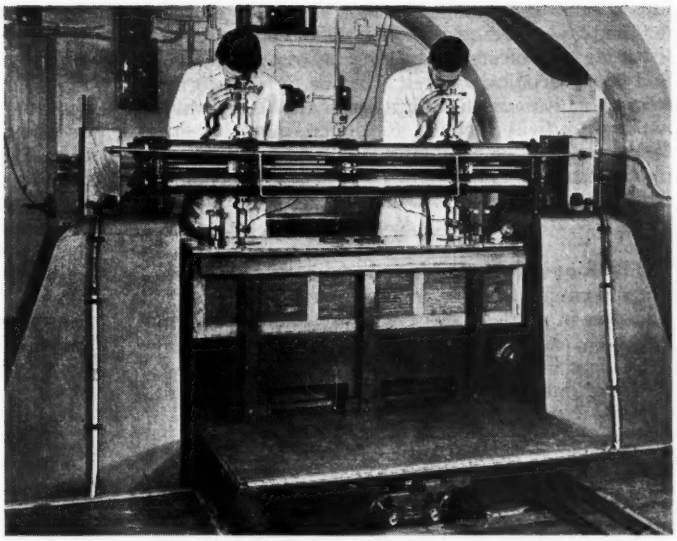


Fig. 3. The NPL one-metre microscope comparator for line-standards

placed side by side, each on one of two parallel girders contained in a double water bath mounted on a carriage capable of being moved in a direction perpendicular to the girders. Each bar is supported on two rollers approximately situated at the Airy points and so spaced that the distance between the defining lines, which are ruled on the exposed neutral plane of the bar (see Fig. 1), has a maximum value. Two micrometer microscopes are rigidly held in brackets supported in such a manner as to be unaffected by the motion of the carriage. Each girder has independent adjustments by means of which the defining lines can be brought into focus in the two microscopes. Each microscope is capable of rotation through 180° about its mechanical axis (which is constructed to be closely coincident with the optical axis) and its objective lens is enclosed in a cell with an optically flat glass window at its base which is submerged below the surface of the water in the inner bath. The water is continuously stirred and the temperatures of the bars are observed by means of accurately calibrated thermometers placed near the standards in the inner bath. Readings are taken by means of the microscopes alternately on the two defining lines of each bar and then again with the microscopes rotated through 180° to minimise the effect of any asymmetries in the illumination and in the sectional profiles of the defining lines. In good conditions a single visual setting, made by moving a pair of parallel cross-wires in the image plane under the control of the micrometer drum until the wires are placed as symmetrically as possible about the line image, has a standard deviation of 0.3μ (12 micro-inches). The setting is subject to personal errors, and a complete set of observations, consisting of 16 readings by each of two observers and occupying about 30 minutes, is designed to minimise such errors and to interchange observers between the microscopes. Four such sets are made, the bars being turned end for end under the microscopes and interchanged on their girders in a symmetrical fashion, so that 64 observations of length are made in all. The standard deviation of the mean result is usually better than 0.1μ (4 micro-inches).

The divisions of a precision scale are calibrated in a similar way, except that the carriage of the subdividing comparator moves along the direction of the bar, that is longitudinally instead of transversely. The microscopes are fixed at a series of suitable intervals apart, e.g., 1 dm (decimetre), 2 dm, 3 dm, etc., for a metre scale divided in decimetres, and each interval of 1 dm, 2 dm, etc., is compared with every other interval of the same magnitude throughout the scale. Smaller intervals are calibrated in a similar manner.

Recent developments: To improve the accuracy of comparing line-standards and scales, two impersonal methods are in course of development at the NPL. Both are more precise than that depending on visual observations through microscopes and both can be applied to direct interferometric determinations of line-standards in terms of light waves. In one method [7], special camera microscopes replace the usual two microscopes in the transverse comparator and record on two plates the relative positions of the corresponding defining lines on the two standards under comparison. An analysis of the gradients of optical density in magnified images of the defining lines, recorded on photomicrographs in this manner, has demonstrated the possibility of defining their position to an accuracy of 0.05μ (2 micro-inches) or better. A suitable measuring machine has accordingly been constructed for use as an accessory to the photographic comparator. With this machine the micro-densitometric procedure is applied, using a photoelectric cell as detector, to measure the relative positions of the line images on each photomicrograph.

In the other impersonal method [8], a photomultiplier cell replaces the function of the human eye

in a special design of microscope. The image of the defining line produced by the microscope objective is caused to oscillate across a slit in front of the cell, and the variation of cell current is transformed electronically into an indication of the line position, with a sensitivity of 0.02μ (0.8 micro-inch) or better for settings on good quality lines. Other forms of photoelectric microscope with similar performances have been developed elsewhere for application in the transverse and longitudinal types of comparator.

Measurement of longer distances: The invar tapes used for measuring long base-lines and other distances in geodetic surveys, or for civil engineering purposes, are verified under microscopes on a long measuring bench in the standards laboratory by a process depending on addition, commencing from line-standards representing the fundamental units of length. To begin with, a bar 4 m or 12.5 ft long divided in metres or yards and fractions thereof, is compared metre by metre, or yard by yard, etc., with the fundamental line-standard in a large transverse microscope comparator. This bar is in turn compared either with suitable reference marks engraved on metal plates let into the masonry base of the measuring bench (usually 50 m long) at intervals corresponding to the length of the bar, or else directly with the divisions of the tape to be verified, which is suspended in single or multiple catenary (and sometimes supported on a flat surface) under tension. In the best work an accuracy of 1 part in 2 millions is achieved in the standardisation of a 24 m tape. Although invar is the material commonly used for the construction of geodetic standards because of its low thermal expansivity, the mechanical properties of invar (including its secular stability) are poor and the tapes require careful manipulation in use to avoid damage. Some precise surveying has been done with steel tapes (having a much higher thermal expansivity but better mechanical properties, including stability) for which the relation between length and electrical resistance, determined in the laboratory over a wide range of ambient temperatures, is used in the field to determine length from measurements of electrical resistance.

Light-wave interferometry has been successfully employed to establish the distances between the datum marks on a 50 m. measuring bench under laboratory conditions, and even for distances up to nearly 1 km under suitable atmospheric conditions in the field. Interferometry over distances of several metres, using radio microwaves in the millimetre range of wavelengths, has been applied by Dr. K. D. Froome at the NPL to determine the velocity of propagation of electromagnetic waves [9]. An instrument known as the geodimeter [10], originally developed by E. Bergstrand in Sweden to measure the velocity of light, is now successfully applied to the measurement of geodetic base-lines to an accuracy within 2 parts in a million. The method depends on measuring, by electronic means controlled by a quartz crystal frequency standard, the time taken by high-frequency light-pulses, generated in a beam transmitter situated at one end of the base, to travel to a mirror placed at the other end (say 20 km away) and back to the transmitter. As the velocity of light is now known to about 1 part in a million, the distance travelled can be calculated to similar accuracy provided the effect on velocity of the atmospheric conditions along the base can be properly assessed. Another instrument for measuring long bases, depending on the principle of the radar transponder used for aircraft recognition and known as the tellurometer [11], was introduced in South Africa by T. L. Wadley in 1956. It has recently been checked in this country by using it to measure known base-lines and so determining a value for the velocity of propagation of electromagnetic waves which agreed to well within 1 part in a million with the accepted value.

End-standards and their calibration: The most familiar form of end-standard is the slip or block gauge, made of hardened steel with highly finished, flat and parallel measuring faces, and first introduced by C. E. Johansson (Sweden) in 1896. In sizes up to 4 in. (10 cm) the rectangular section of this form of gauge has been found particularly suitable for a wide variety of measurements in precision engineering. Greater lengths than 4 in., up to 1 yard or 1 m and longer, are convenient to construct and use in the form of cylindrical steel rods or bars with only the ends hardened [12]. This form of highly precise standard*, which was designed at the NPL, has a circular section, $\frac{7}{8}$ in. diameter, and bears two slightly raised bands at the Airy positions of support, which are symmetrically disposed at a distance apart equal to the fraction $1/\sqrt{3}$ ($= 0.577\ldots$) of the length of the bar. These supporting positions endue the standard with the property that the end-faces remain parallel when the bar is supported horizontally on the bands. Gauge manufacturers in this country supply this form of end-standard in lengths down to 1 in.

The well-known property of wringing which enables additive combinations of end-standards to be formed is of great utility to the precision engineer and the standards laboratory, for it provides the means of building up a large number of combination standards by selection from a set containing a limited number of gauges arranged in a suitably graded series of sizes. For workshop use end-bars are provided with threaded recesses at the ends into which stud screws are assembled so that the wrung joints between the gauges are internally supported. An improved design of screwed connection for the workshop combination end-bar, recently introduced at the NPL by L. W. Nickols [13], reduces the change in length at each joint, due to distortions caused by the screw connections, to about 1 micro-inch and is insensitive within wide limits to the amount of torque applied. This innovation renders the screwed connection capable of application to the reference grade of end-bar.

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* See, for instance, in BS1790: 1952 "Length Bars and Accessories", the specification for the reference grade of end-standard.

Measuring machines of different types, and varying sensitivity, are available for comparing end-standards by contact measurement [12]. In these the standard is measured between two opposed anvils, one of which may be fixed, or may be movable by means of a micrometer screw, while the other is capable of a small movement operating some form of sensitive indicator. This indicator amplifies small movements by means of a mechanical, optical, electrical or pneumatic principle, or by a combination of two or more of these principles. The two standards to be compared are inserted between the anvils, and if the whole difference between them is sufficiently small, the movement of the indicator over a calibrated scale suffices to determine it. If the difference is greater, the indicator is brought to a fixed mark by an adjustment of the moving anvil, the difference in length then being ascertained by the difference in reading of the micrometer drum.

As the fundamental units of length are defined at present by line-standards, an essential operation in the calibration of reference end-standards is that of transfer from line to end measure by means of a classical metrological procedure [12]. The process of determining end-standards representing fractions of the fundamental units is accomplished by comparing together, in suitable highly sensitive comparators or end-measuring machines, wrung combinations of equal nominal size. Analogously with the process of subdivision already outlined for scales, the basic end-standard (36 in.) is compared with a combination of two 18 in. standards or of three 12 in. standards. Inter-comparison of the two 18 in. standards or the three 12 in. standards then provides information enabling the size of each of the smaller standards to be expressed in terms of the 36 in. standard.

A well-known instrument for comparing end-standards of the same nominal size is the Brookes level comparator [12]. As an instance of the very high precision attainable with the level comparator under laboratory conditions, I quote below the results recently obtained at the NPL by C. O. Taylerson in the intercomparisons of three 1 m end-standards. These standards are denoted by the letters A, B and C and the following are the differences actually observed, together with the adjusted values of the differences :

	Differences (inch)	*Adjusted Values (inch)*
A - B =	$+0.000\,463_8''$	$+0.000\,463_3''$
B - C =	$-0.000\,927_6''$	$-0.000\,928_1''$
C - A =	$+0.000\,465_4''$	$+0.000\,464_9''$
Sum	$+0.000\,001_6''$	$+0.000\,000_1''$

The sum of the three differences departs from zero by only +1.6 micro-inches, an amount which, divided equally between the three differences, yields an adjustment of only —0.5 micro-inch to each value, equivalent to 1 part in 80 millions of each metre length.

The interferometry of length : The process of mechanical subdivision of end-standards becomes laborious when extended to the smaller sizes, and it is now largely superseded, for sizes less than 18 in. and 50 cm, by direct interferometric methods of calibration. Owing to their optical perfection of finish the terminal faces of an end-standard can be arranged in an interferometer to serve as mirrors, over which is produced, utilising the phenomenon of light-wave interference, simple patterns of alternate bright and dark bands or fringes. If the positions of these interference fringes are suitably measured or assessed in, say, four monochromatic beams of differing wavelengths known in terms of the yard and the metre, information is obtained from which the distance between the reflecting faces of the end-standard is evaluated in numbers of waves, which are then converted into terms of the customary units of length.

The interferometry of an end-standard would be more convenient if both ends faced the same way. In the NPL-Hilger gauge-measuring interferometer [14] illustrated in Fig. 4, this convenience is achieved by wringing one end of the standard to a flat, reflecting base-plate of larger area so that the projecting portions of the latter face the same way as the other end of the standard. As earlier NPL work [15] has indicated that the size of the wringing interval between two flat surfaces wrung together is only of the order of 0.2 micro-inch (0.005μ), the use of the auxil ary base-plate and the inclusion of the wringing interval in the size of the end-standard is of very little practical significance. Moreover, most national specifications for slip and block gauges, including BS 888 : 1950, define length in such a manner as to include the wringing interval in the practical length of an end-gauge.

Evidence of the very great reliability both of the light wave as a standard of length and of the interferometric process of measurement is submitted in the results tabulated below. These refer to the measurements of a set of 81 slip gauges of the calibration grade purchased from a British manufacturer and first measured in 1951, and sent since then to the Laboratory for periodical calibration. The set is utilised by the consignors for reference purposes and is therefore carefully preserved and used only occasionally. The measurements were made in the ordinary course of routine with the NPL design of interferometer shown in Fig. 4 or with one of its earlier prototypes. In the table the values quoted represent the errors from the nominal sizes at 20°C (68°F) in micro-inches.

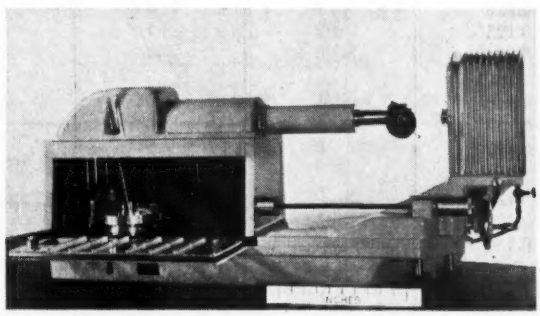

Fig. 4. The NPL-Hilger gauge-measuring interferometer

MEASUREMENT OF A SET OF SLIP GAUGES

OVER THE PERIOD 1951 - 1957

Nominal size (inch)	*February,* 1951	*May,* 1952	*December,* 1953	*April,* 1955	*September,* 1956	*October,* 1957
0.1001″	+2	+1	+2	+1	+1	+1
0.1002″	—3	—3	—3	—2	—3	—3
0.1003″		—1	—1	—1	—1	—1
0.1004″		—1	—1	—1	—1	0
0.1005″	+1	+1	0	+1	0	+1
0.1006″	0	—1	—1	—1	—1	—1
0.1007″	—2	—2	—3	—3	—3	—3
0.1008″	+3	+2	+2	+2	+2	+2
0.1009″	—2	—2	—2	—2	—2	—2
0.101″	+1	0	0	0	0	0
0.102″	—3	—4	—4	—3	—3	—4
0.103″	—3	—3	—3	—3	—4	—3
0.104″	0	0	—1	0	—1	0
0.105″	—2	—2	—2	—2	—2	—2
0.106″	—3	—3	—3	—3	—3	—3
0.107″	+1	+1	+1	+1	0	0
0.108″	—2	—3	—3	—3	—3	—3
0.109″	0	—1	—1	—1	—1	0
0.110″	—3	—4	—4	—4	—4	—3
0.111″	+1	0	0	0	0	0
0.112″	0	—1	—1	—1	—1	0
0.113″	0	—1	—1	—1	—1	0
0.114″	+3	+2	+2	+3	+2	+3
0.115″	+1	0	0	0	0	0
0.116″	0	0	0	0	0	0
0.117″	—3	—3	—4	—3	—3	—3
0.118″	—2	—2	—2	—2	—2	—2
0.119″	—1	—1	—2	—1	—1	—1
0.120″	+1	+1	0	+1	+1	0
0.121″	+1	+1	0	+1	+1	+1
0.122″	+2	+2	+1	+1	+1	+1
0.123″	+2	+1	+1	+1	+1	+2
0.124″	0	—1	—1	—1	—1	—1
0.125″	—1	0	—2	—1	—2	0
0.126″	+1	0	0	0	0	0
0.127″	0	0	0	0	0	0
0.128″	0	0	—1	—1	—1	—1
0.129″	+1	+1	+1	+1	+1	+1
0.130″	—1	—1	—1	—1	—1	—2
0.131″	0	—1	—1	—1	—1	—1
0.132″	+1	0	+1	0	0	+1
0.133″	+1	0	0	0	0	0

Nominal size (inch)	*February,* 1951	*May,* 1952	*December,* 1955	*April,* 1955	*September,* 1956	*October,* 1957
0.134″	—1	—1	—2	—2	—2	—1
0.135″	—2	—2	—1	—2	—2	—2
0.136″	+1	+1	+2	+1	+1	+1
0.137″	—2	—3	—3	—2	—2	—3
0.138″	0	—1	0	0	0	0
0.139″	+1	0	0	0	0	0
0.140″	+1	0	+1	+1	+1	+1
0.141″	+2	+1	+1	+1	+1	0
0.142″	+3	+2	+2	+2	+2	+1
0.143″	—1	—1	—2	—1	—1	—1
0.144″	+1	+1	+1	0	0	+1
0.145″	—1	—1	0	—1	—1	—1
0.146″	0	0	—1	—1	—2	—1
0.147″	+1	0	0	+1	0	0
0.148″	—1	—1	—2	—1	—2	—2
0.149″	0	—1	—1	—2	—2	—2
0.05″	+2	+2	+2	+2	+2	+2
0.1″	—3	—4	—3	—4	—3	—4
0.15″	0	—1	—1	—1	—1	—1
0.2″	0	0	0	—1	0	0
0.25″	—1	—2	—2	—1	—2	—2
0.3″	+2	+1	0	+1	0	0
0.35″	0	—1	—1	—1	—1	—1
0.4″	0	0	0	0	0	0
0.45″	—1	—1	—2	—1	—2	—2
0.5″	+2	+1	+1	+1	+1	0
0.55″	+1	+1	0	+1	0	0
0.6″	0	—1	—2	—1	—1	—1
0.65″	+1	0	—2	—1	—1	—2
0.7″	+2	+3	+1	+2	+2	+2
0.75″	+2	+1	0	+1	0	0
0.8″	+3	+2	+1	+2	+2	+1
0.85″	0	0	—2	—2	—2	—2
0.9″	+1	+2	+1	+2	+2	+2
0.95″	+1	+1	—1	—1	—1	—1
1″	+1	+1	—1	—1	—1	0
2″	(—6)	(—7)	(—9)	(—10)	(—7)	—9
3″	(—2)	(—2)	(—2)	(—1)	(+1)	+1
4″	(+11)	(+12)	(+10*)	(+5)	(+2)	+2

* *Replacement gauge.*

NOTE—The values for the 2″, 3″ and 4″ gauges in parentheses were obtained by mechanical comparison with Laboratory standards (maintained interferometrically) in a Sears millionth machine [12], because the earlier models of the NPL interferometer were limited to measurements up to 1″. From 1956, all sizes up to 4″ (10 cm) have been measured interferometrically in the routine test work.

An interesting point to be noted from the results on pages 9 - 10 is the stability of this representative set of slip gauges. The data is being prepared for statistical examination because certain gauges show slight evidence of very slow secular changes; these would be impossible to detect with certainty by mechanical methods of measurement unless continued over a much longer period of time.

By utilising the earlier mentioned sources of monochromatic light in which pure isotopes are the emitters of radiation, the range of direct measurement may be extended to 1 yard and 1 m by using an appropriate form of interferometer, such as the Kösters-Zeiss equipment with 1 m capacity [16] and capable of an accuracy of 1 part in 10 millions or better. The principles used for the interferometry of greater lengths are the same as, or are extensions of, those developed for the earlier mentioned determinations of the metre in light waves.

Standards of mass

General description: The Imperial Standard Pound, representing the avoirdupois pound of 7,000 grains, was constructed in 1844 and is in the form of a solid cylinder of platinum. When the metric system was first established during the last decade of the 18th century, the kilogram was defined to be equal to the mass of a cubic decimetre of water at the temperature (about 4°C) of its maximum density, and the first permanent representation was the Kilogramme des Archives, also a solid cylinder of platinum. As in the case of the metre, practical realisation of the original definition proved inconvenient and insufficiently precise, so the specification in natural terms became superseded by the platinum standard. In its turn, this was replaced in 1889 by the International Prototype Kilogram, in the form of a solid cylinder of height equal to its diameter and made of the same platinum-iridium alloy as the Metre.

In the United States the pound is defined as 0.453 592 427 7 kg, from which 1 kg = 2.204 622 34 lb (U.S.). This ratio was, in fact, determined in 1883 for the United Kingdom pound by the Board of Trade Standard Weights and Measures Department in co-operation with the International Bureau of Weights and Measures, but when given legal sanction in the United Kingdom by Order in Council (SRO. 1898, No. 411) for use as a conversion factor for purposes of trade, the rounded value, namely, 1 lb (U.K.) = 0.453 592 43 kg [equivalent to 1 kg = 2.204 622 3 lb (U.K.)] was adopted. Subsequent determinations of the pound (U.K.)/kilogram ratio made at the NPL gave the following results [with the earlier value (rounded) included for ease of comparison] :-

Date	*Mass of 1 lb. (U.K.) in kg*
1883	0.453 592 428
1922	0.453 592 343
1933	0.453 592 338

The two later values are in very close agreement but their mean differs by about 1 part in 5 millions from the 1883 value, the change probably being due to abrasion caused by excessive use of the standard. As for the yard and metre, a recommendation was made in the Hodgson Report [5] to redefine the pound in terms of the kilogram, using a relationship acceptable in the British Commonwealth and the United States. The values under consideration are 1 lb = 0.453 592 37 kg or 0.453 592 3 kg, both being exactly divisible by 7 so that exact relations with the grain are derivable.

Elaborations of construction and manipulation of a balance are required for the accurate comparison of primary standards of mass. It is also necessary to take great care to preserve constancy of temperature in the balance room to maintain a steady relationship between the arm-lengths of the balance beam, and the observer should work outside the room, all the manipulations of the balance, as well as the standards, being effected by remote controls. Movements of the balance beam are observed by noting the movement across a scale of a spot of light reflected by a small lens-mirror attached to the beam. Fig. 5 illustrates the precision knife-edge balance [17], of capacity 1 kg, installed at the NPL for weighings of the highest accuracy, particularly of the national standards of mass. It has been shown to be capable of an accuracy of one millionth of a gram in the comparison of two 1 kg standards of suitable quality, an accuracy equivalent to 1 part in 1000 millions.

Materials: A fortunate choice was made by using platinum and platinum-iridium, and particularly the latter, for constructing the primary standards. The degree of consistency, within 2 parts in 100 millions, with which recomparisons of various national copies of the kilogram have in general repeated the original determinations convincingly demonstrates the suitability of the standards as well as the perfection of the balances used. The following results have been obtained for the British copy (No. 18) at the International Bureau :-

Year	*Mass (kg)*
1889	1.000 000 070
1924	1.000 000 051
1933	1.000 000 058
1948	1.000 000 071

The recommended materials [18] for reference standards of mass (which are usually designated as "weights") of nominal value above 0.5 gram (6 grains) are, in order of preference with regard to stability :-

(i) platinum-iridium (90/10);

(ii) platinum;

(iii) austenitic stainless steel (25% chromium, 20% nickel);

(iv) non-magnetic nickel-chromium (80/20);

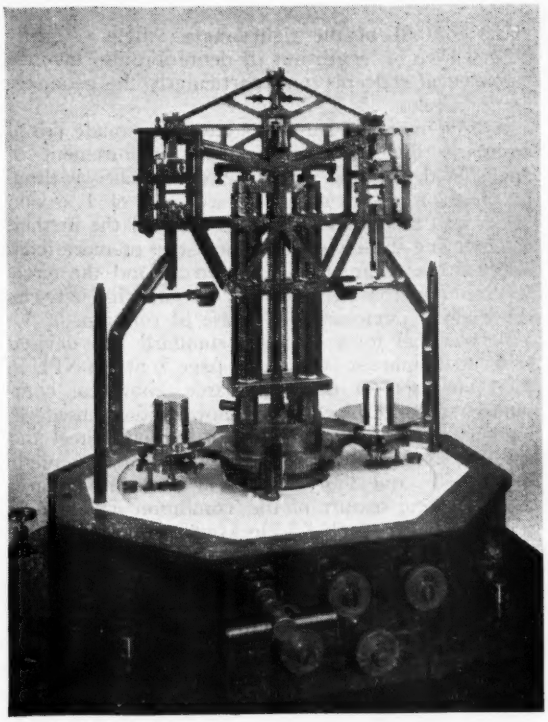

Fig. 5. The NPL precision balance for weighings of the highest accuracy (cover removed)

(v) brass, plated to a minimum thickness of 0.015 mm (0.0006 in.) with rhodium, platinum or chromium over a suitable underplating, or with tin-nickel alloy (65/35).

Pure nickel is not a suitable plating material because of its magnetic properties and its liability to become "fogged" in service. For smaller weights, materials (i) to (iv) above are preferred, with the addition of (vi) gold, (vii) tantalum and (viii) aluminium (for standards of 0.1 gram, 1 grain and smaller).

Buoyancy correction: In the comparison of two standard masses in air, allowance must be made for the upward buoyant effect of the volumes of air they respectively displace. The upthrust experienced by each standard is proportional to its volume and the density of the air. If M is the value of a weight of density ρ, obtained by balancing in air against a mass standard of density ρ_w without making buoyancy corrections, its mass is given by $M + M\rho_a [(1/\rho) - (1/\rho_w)]$, where ρ_a, is air density. In the practice[18] adopted at the NPL for the standardisations to Class A accuracy (1 part per million on the larger weights), each member of a set of weights, including the fractional weights, is standardised on the basis of balancing, in air of density 0.0012 g/ml (gram per millilitre), a standard of the same nominal mass having a density equal to a suitably rounded value representing that of the larger members of the set, namely, 8.4 g/ml for nickel-chromium and brass, and 8.0 g/ml for stainless steel. In use, buoyancy corrections, if significant, should then be based on these densities. For many purposes the representative value of air density quoted above is suitable, but if high accuracy is required, allowance has to be made for variations in air density from this value.

Standards of time and frequency

The lapse of time is measured by means of clocks in which repetitions of some regularly occurring event are counted and indicated. Typical examples of periodic phenomena that are used as "clocks" are (i) the revolution of the Earth about the Sun or the rotation of the Earth on its axis, (ii) the swing of a pendulum or of a balance wheel, (iii) the electro-mechanical oscillations of a quartz crystal, and (iv) the natural periodicities of molecules and atoms. Any of these phenomena may be used to define a standard of time or of frequency, i.e., the number of periodic events in unit time. Because of the need to distinguish between an instant of time (or epoch) and a time-interval, our conception of time appears to be dichotomous. To define an instant of time a scale must be established by selecting an arbitrary zero and maintaining a record of the number of cycles completed by the standard since the chosen zero of time; to measure a time-interval it is necessary to observe the number of cycles of the standard which occur between two instants denoting the beginning and end of the interval. The difference is more apparent than real, but the dichotomy is clear if I make the statement: "I caught a train at 09.35 on Thursday, 31st October, 1957, and the journey lasted 2 hours 43 minutes."

The primary requirements of a standard clock for defining the epochs of astronomical and historical events are continuity and regularity of operation; these are satisfied by the motions of bodies in the solar system which denote the day, the lunar month and the year. The smallest interval provided by the astronomical clock is the day, and this is subdivided into hours, minutes and seconds by pendulum clocks and chronometers. Quartz frequency standards, originally introduced to measure frequencies in radio engineering practice, are gradually assuming the function of mechanical clocks for measuring time to very high precision. Although the quartz clocks are highly stable, they are not sufficiently so for use as standards to define the unit of time. Their indications are adjusted in terms of the astronomical standards and then used to smooth the errors of the astronomical observations and for interpolating

between them. Recent developments in radio frequency spectroscopy have made it possible to relate these working standard quartz clocks to the natural periodicities of molecules and atoms. A caesium atomic frequency standard [19] has been in use for this purpose at the NPL since June, 1955.

Two astronomical time standards [20] are now recognised: the rotation of the Earth on its axis which gives the mean solar day, and the revolution of the Earth about the Sun which gives the tropical year. The latter is the means of defining the second of time for scientific, and particularly astronomical, purposes, but the former, from which the mean solar second is derived, is more convenient for civil use and, indeed, for most scientific and industrial purposes. The relation between the two seconds can be obtained, but only retrospectively because (a) the Earth is found to be somewhat variable in its time-keeping, as illustrated by the periodic change in rate of rotation shown in Fig. 6, and (b) the second defined by means of the tropical year can only be precisely established from astronomical observations extending over long intervals of time. Despite these difficulties, the mean solar second obtained through the intermediary of the time signals broadcast from the Royal Greenwich Observatory through Rugby is maintained uniform over a period of a year to about 5 parts in 1000 millions. These signals are used to calibrate a group of Essen-ring quartz clocks (frequency 100 kc/s) which is maintained at the NPL as a frequency standard and has a day-to-day stability of 1 part in 10,000 millions, corresponding to 0.000 01 second per day. The mean frequency of this group of clocks is periodically calibrated in terms of the caesium atomic standard to the same accuracy.

Standards of angle

The logical unit of angle is the radian — the angle subtended at the centre of a circle by an arc of length equal to the radius. In the sexagesimal system of angle measurement the basic unit is the right angle (of 90°) defined either as the angle between two straight lines intersecting so that adjacent angles are equal, or as the angle subtended at the centre of a circle by an arc of length equal to one-quarter of the circumference. Another unit of angle, used in the metric system, is the grade equal to 0.01 of the right angle. Angle is partly a derivative of length but its definition also involves geometrical concepts, and particularly the geometry of the circle.

Astronomers and surveyors have long made use of circularly divided scales for the measurement of angle. With the best modern circular scales as fitted to precision goniometers, an accuracy of 1 second of arc can be obtained if use is made of the method of observing the divisions through two or more fixed microscopes symmetrically spaced around the circle to eliminate the effect of any eccentricity between the divided circle and its centre of rotation.

A practical form of angle standard was devised by G. A. Tomlinson (see ref. 12, page 5) at the NPL in 1941, and sets of these standards, known as combination angle blocks, are now widely used in industry. The blocks are made of hardened steel and can be combined by wringing to form any angle between 0° and 360° in steps of 3 seconds of arc; an interesting feature of the Tomlinson set of angle standards is that only 13 blocks are required for this purpose. If three sets are constructed at the same time it is possible to calibrate the individual standards, without reference to other standards of angle, by means of an autocollimator method in which the geometrical properties of parallelism (or zero angle) and squareness (or 90°) are utilised. The accuracy of adjustment to the nominal sizes is 2 seconds and the calibration accuracy is 1 second. For routine purposes of verification a simple comparison is made, block by block, with a reference set of standards, again using the autocollimator.

Angle standards of polygonal form with a number of equally inclined facets are made either of hardened steel or of glass (also fused silica) with aluminised or rhodiumised working faces. Used in

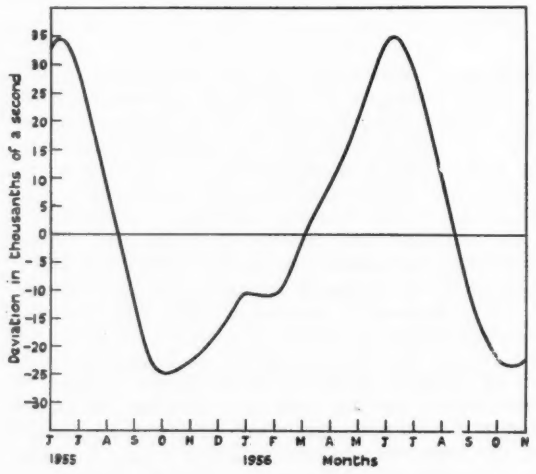

Fig. 6. Variation in the rate of rotation of the Earth, relative to the NPL caesium standard

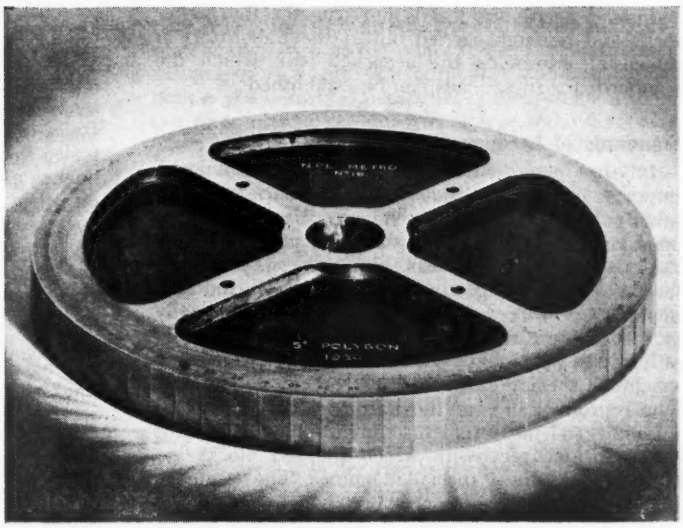

Fig. 7. Precision angle standard in the form of a polygon with 72 facets

association with an autocollimator they are of great utility in verifying circularly divided scales. Like the combination angle blocks, they can be self-calibrated to an accuracy of 1 second without reference to any other standards of angle. Exact centring is not essential in their applications. As an example of the high precision of construction attained in British manufacture of engineering standards, the following results are quoted relating to a polygon with 72 facets (5° interval) recently certified at the Laboratory. The corresponding NPL reference standard is illustrated in Fig. 7. The mean departure from nominal size of every angular interval between the datum (zero) facet and any other facet was 2.9 seconds, with a range from —7.9 to +5.7 seconds; the average error of the 5° angles between adjacent pairs of facets was 3.3 seconds, with a range from —10.0 to +8.5 seconds.

Standards of force or load

It has already been mentioned that technical measurements of force are usually standardised by reference to the weight of a given mass, and it is the general practice to use the weights of the pound and the kilogram as the two units of force. Since gravitational acceleration varies over the Earth's surface, the weight of a given mass varies likewise; and for stations at sea-level this variation amounts to about 1 part in 200 from the equator to the poles. It is accordingly necessary in precision work to specify the associated value of gravity when expressing a force in terms of weight. Standards laboratories have accordingly adopted for this purpose the internationally accepted value of standard gravity, namely, $g = 980.665\ cm/s^2$. The equivalent in the foot-pound-second system of units is nominally $32.1741\ ft/s^2$. Allowance for atmospheric buoyancy (see page 12) is made in the best work and this entails, closely enough, a correction to the weight of 1 part in 7,000. As the value of gravity at Teddington is $981.183\ cm/s^2$ ($32.1911\ ft/s^2$), the reduction to standard gravity involves a correction of 1 part in 2,000 in the opposite sense to that for buoyancy. The masses of the weights in the 50-ton and 5-ton standard deadweight machines at the NPL are adjusted, for buoyancy and gravity, so that they provide loads in terms of the two recognised gravitational units of force to an accuracy within 1 part in 25,000.

The two deadweight machines, which may be used for compressive and tensile loads, constitute the means for calibrating the proving rings and other load measuring devices used in industry for verifying compression and tension testing machines. They are also used for calibrating the Laboratory's secondary standards of load, mainly of the resistance strain gauge type, for loads beyond 50 tons. To take one example, a 250-ton load cell built of five identical struts, mounted symmetrically between two flat and parallel end plates, can be standardised to an accuracy of 1 part in 400 by calibrating each strut individually in the 50-ton deadweight machine. It is the intention of the Laboratory to extend its range of standards up to 1,000 tons in compression, and a 1,200-ton hydraulic compression machine (see Fig. 8) has recently been installed for the work. Using the "pick-a-back" method illustrated in Fig. 8 and the relationships $50 + 50 + 50 = 150$, $150 + 150 + 150 = 450$, etc., it is practicable to develop standards which are basically related to the fundamental 50-ton deadweight machine. Standards of these higher denominations can similarly be developed for measuring loads in tension. In this field of metrology the accuracy realisable for loads up to 50 tons, which is obtained from the deadweight machines, is more than sufficient to meet every

industrial need; but this is not true for the higher loads and research carried out at the Laboratory is aimed at improving the accuracy with which the standards for these loads can be established.

Standards of hardness

In the measurement of hardness, which is of importance to the metal-working industries, one or other of the established indenting techniques is commonly employed. To ensure uniformity in hardness testing by these means it is necessary for the lever-type indenting machines, on which industry depends, to be properly maintained and periodically verified by means of test blocks of known values of hardness which have been determined by indenting machines specially designed to serve as standards. The reproducibility of the hardness scales provided for industrial measurements thus ultimately depends upon the accuracy with which the test blocks are calibrated by these special machines. The tendency is to specify hardness much more rigidly than can be justified by the performance hitherto attained in any stage of the system of control outlined above.

Though of simple conception, the indenting technique is in practice affected by difficulties which become severe when the highest accuracy is sought. One of these is that of analysing the errors of the process, which originate from several sources all exerting their influences simultaneously. It is easier to isolate the sources of error when the Vickers method is employed, and the NPL has designed and constructed a new deadweight indenting machine [21] using a 136° diamond pyramid indentor and standard loads of 30, 50, 100 and 120 kgf* (see Fig. 9). In addition, a new design of measuring microscope has been developed by means of which the size of the indentation can be more accurately measured. To establish the accuracy of measurement of this new indenting machine it was necessary to produce test blocks of better uniformity of hardness than those normally available, and research carried out at NPL into methods of hardening, grinding and polishing was successful in providing these. Further work remains to be done to cover the full range of hardness, but it has already been established that the accepted practice of making five indentations will establish the hardness of a uniform block at the 600 - 950 DPN † level within the target figure of ± 10 DPN at which the research aims.

Attention is also being given to the development of a new standard deadweight machine for the Rockwell scales of hardness ††. In the case of the Rockwell C scale, investigations have been made into the influence of the form of the conical diamond indentor on the hardness value obtained. Methods of measuring the form accurately have been developed[22] and have been correlated with performance in the indenting machine [23]. It was shown in this work that errors in roundness of the section of the cone played a significant part and also that a factor hitherto ignored, namely, the relationship of the crystallographic axis of the diamond to the axis of the cone, must also be taken into account. Much further work remains, but the very successful outcome of the work on the DPN scale permits the hope that good progress will also be made in providing for industry's needs in the Rockwell scale.

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* A proposed symbol for the unit kilogram-force.

† See BS 427 : 1931 for the definition of the diamond pyramid hardness scale.

†† See BS 891 : 1940.

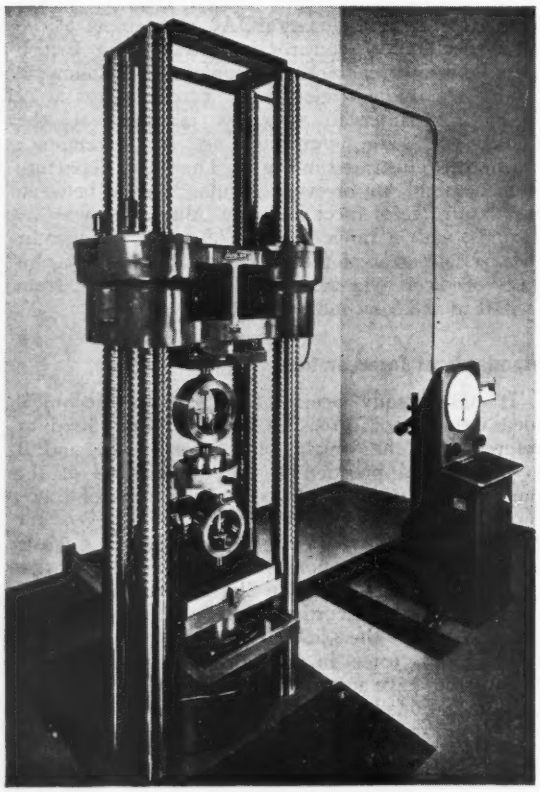

Fig. 8. Use of a 1,200-ton compression machine for calibrating a 135-ton load standard by build-up from three 50-ton standards

Conclusion

This account of the bases of measurement, and a little of the superstructure, will not, I hope, give the impression that the standards laboratory, in its work on the improvement and maintenance of fundamental and derived standards of measurement, is concerned with degrees of accuracy too academic to be of any possible interest to the production engineer. Such achievements in measuring accuracy as are represented by the millionth of an inch and the second of arc are certainly not outside his interest, for there is an increasing demand from industry for verifications of its standards of length and angle to these accuracies. The work I have described on the establishment of more precise standards of load and hardness is again a direct consequence of industrial requirements, and it can certainly not be said that the accuracies of the standards are unduly ahead of modern requirements in materials testing. The needs of the radio engineer in the control of emission frequencies have likewise been at least partly responsible for the introduction of better standards of reference such as the quartz crystal oscillator and, ultimately, the atomic frequency standard. But besides the industrial necessities of measurement there are those of science, and it is as true today as it was when Lord Kelvin made the remarks quoted in the introduction to this Paper that metrology is a means for the advancement of knowledge**. I believe it was a political contemporary of Lord Kelvin who once exclaimed against "these damned dots"; in science a shift of the certainty of measurement to the next decimal place invariably leads to new knowledge of the processes of nature. In due course this new knowledge may become applied to the development of novel technological resources of direct concern to the production engineer.

**See, for instance, "The Contribution of Measurement to Discovery", by Sir Harold Hartley, G.C.V.O., F.R.S., *Machinery Lloyd* (European Edition), 7th September, 1957.

Fig. 9. A new NPL machine for establishing the standard of hardness in the DPN scale

Acknowledgments

I am greatly indebted to several colleagues at the National Physical Laboratory, and particularly Dr. J. C. Evans, Mr. P. H. Bigg, Dr. L. Essen and Mr. J. V. L. Parry, for advice and assistance in the preparation of this Paper, which is published by permission of the Director of the Laboratory.

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REPORT AND DISCUSSION

Chairman:

THE RT. HON. THE EARL OF HALSBURY, F.R.I.C., F.Inst.P.,
President of the Institution.

OPENING the meeting, Lord Halsbury said that it was his duty and pleasure as President of the Institution to introduce Dr. Barrell, who was to deliver the sixth Sir Alfred Herbert Paper of the Institution. It would, however, be the wish of members that he should first extend thanks to the Royal Institution, its officers and its servants for putting their famous lecture theatre at the disposal of the Institution, and for the time and trouble which they had taken in making arrangements for the Exhibition.

It seemed a sad occasion in one sense, because in introducing the 1957 Sir Alfred Herbert Paper some reference must be made to the passing of Sir Alfred. In 1956 the President of the Institution was in a position to offer him the congratulations of the Institution on reaching his 90th year. The death of a man who passed away at a very advanced age, full of useful years and honours, and with the esteem of his fellow men was not untimely, but the sense of regret that he would not be seen again among his fellows was nevertheless swift and keen.

Shaping a pattern

Sir Alfred Herbert gave his name to the first of the series of Papers, of which the present Paper was the sixth. It was his wish that the Paper to which he lent his name should be devoted to wider aspects of production engineering than those represented by the confines of the machine shop and similar practice. Although his wish had been respected, no other pattern seemed to have emerged from the list of Papers given so far. The first was by Dr. Rolt on the development of engineering metrology, a subject of perpetual interest to production engineers. After passing through the industrial application of radioactivity by Sir John Cockroft and three Papers in succession on the subject of higher technological education and the education of production engineers, the wheel had come full circle. In the sixth Paper, a return was being made to engineering metrology by Dr. Barrell.

Those present had before them, on the preprint, the author's *curriculum vitae*. The President felt sure that Dr. Barrell would not think it any discourtesy on his part if he asked those present to take the general outline of Dr. Barrell's curriculum as read.

Distinguished men of science were divided sharply into two groups. There were those who might be likened to mountaineers, they scaled one or two spectacular peaks; and there were those who could be likened to geological surveyors, they carefully and steadily mapped out a whole territory through a long and studious lifetime. Dr. Barrell, as the notice in his Paper indicated, had devoted his life to the subject on which he was to lecture. He had been working in the National Physical Laboratory off and on for the last 34 years, and there was no better or more qualified person to talk about engineering metrology.

He then invited Dr. Barrell to present the sixth Sir Alfred Herbert Paper, entitled "The Bases of Measurement".

IN presenting his Paper, which appears on pages 3 - 18, Dr. Barrell said:

I do not think I can do better, in opening this lecture, than quote some remarks which Lord Kelvin made in a lecture which he gave about 74 years ago. Whether it was given in this theatre or not I do not know; but the remarks he made then on the subject of measurement were as follows:-

> "I often say that when you can measure what you are speaking about and express it in numbers you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind."

That, I think, sums up the basis of my Paper.

In analysing the process of measurement I have given in the beginning of the Paper a very elementary example of what we do, for instance, if asked to measure the length of a straight line drawn on a sheet of paper. We take a ruler, divided into inches and fractions of an inch, lay it along the line and find out how much length there is in the line by comparing it with the length on the ruler. It will invariably be found that measurement involves comparison; it involves comparison of the quantity to be measured with a standard, and the standard is known in the terms of the unit of the quantity which is being measured.

I have introduced two terms, "unit" and "standard", and it is important to distinguish

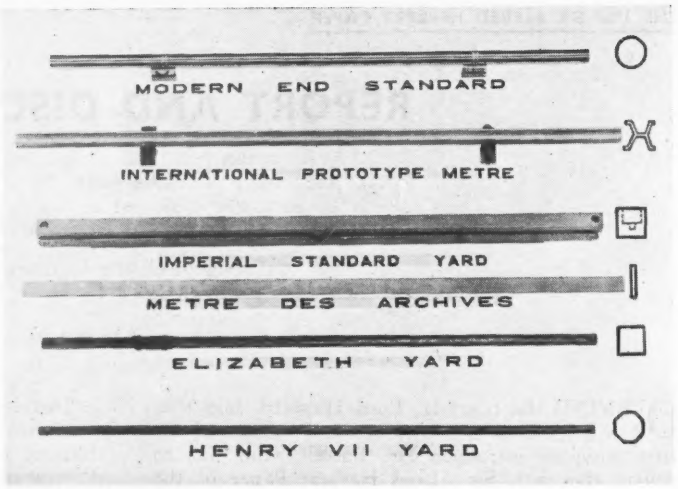


Fig. 10. Various forms of material standards of length, with an indication of the cross-sections on the right

between them. A unit is an entirely abstract conception in my view. It has no meaning at all for practical purposes until you have defined it in terms of some practical standard. You can define a unit in two ways — in terms of material standards, such as the length bars which are to be seen in the Exhibition, or you can define it in terms of some natural constant or natural standard or some "physical situation". A good instance of a natural definition is, as you will see, in time, for which the rotation of the earth about its polar axis is used as a means of defining the day for ordinary purposes. Another natural constant is the revolution of the earth about the sun, giving the year. Also with length, although at present we define it by means of a material standard in the form of a metal bar, it is probable that in the next few years we shall define length by means of another natural standard, namely, the wavelength of light. We might, perhaps, for our purposes have a separate unit and an independent standard for everything we measure, but that would make life very complicated. Therefore, it has been the object of the metrologists to devise systems of measurement in which, by making use of physical laws, it is possible to use the relationships between a certain group of quantities, such as the mechanical quantities in which the production engineer is mostly interested, so that only a few independently defined units are required as the basis of a system of measurement.

For instance, if you take the second law of motion in Newtonian mechanics, you have a relation between length, mass, time and force, and if you assign independent standards to three of those quantities, the fourth can be defined in terms of those three. In the case of the mechanical quantities, you can define velocity, acceleration, moment, force, and so in in terms of length, mass and time, which are generally regarded as the fundamental quantities of measurement in most systems of scientific and industrial measurement. In the metric system we have the metre as the standard of length, the kilogramme as the standard of mass, and the second as the standard of time. In the British Commonwealth and the United States there is also the older system in which the unit of length is the yard, the unit of mass the pound, and the unit of time the second.

For certain purposes in engineering and aerodynamics it is found more convenient to use length, force and time instead of length, mass and time as the fundamental quantities.

Three derived quantities

Before proceeding, I should like to mention three derived quantities — force, hardness and angle — which are also discussed in the Paper. Angle is strictly not solely derived from length, because you have to take into consideration other things besides length. I might also mention here that we have been able to set up an Exhibition in the anteroom to this lecture theatre, where there are certain examples, either in the form of models or the actual standards used, for all the quantities with which I shall deal.

With regard to length standards, I would draw particular attention in Fig. 10 to the Henry VII Yard and the Elizabeth I Yard ; I have been fortunate enough to borrow these interesting, but obsolete, standards from the Director of the Science Museum for this evening. They are end-standards, that is to say, their length is defined by the distance between nominally flat and parallel ends. They are both made of brass. The next one above them is the Mètre des Archives which became the first material representation of the metre. When the founders of the metric system did their work in the last decade of the 18th century, they defined the metre as a certain fraction of a dimension of the Earth, but later they found this inconvenient in practice. It was difficult, when asked to say what a metre was, to have to survey a certain meridian of the Earth. Therefore, it was found to be more convenient to make a material standard which represented that distance, and so the Mètre des Archives became

recognised as the standard of the metre. It is a platinum bar and is also an end-standard.

In historical sequence we come next to the Imperial Standard Yard which was established by the Weights and Measures Act of 1856. It is a bronze bar of 1 in. square cross-section, with a $\frac{1}{2}$-in. hole drilled near each end to half the depth of the section, and at the bottom of each hole there is a gold plug on which is ruled a pattern of defining lines. This bar is called a line-standard because its length is defined by the distance between two parallel lines engraved on the bar. The lines are ruled on the neutral plane of the bar, because it is the least affected plane when one varies the conditions of support. It has long been thought that there was a good deal of evidence to show that the Imperial Standard Yard had contracted by some two ten-thousandths of an inch during the first 20 years of its life, and in 1947 we discovered, on the basis of indirect comparisons with the International Metre made during the previous 50 years at the National Physical Laboratory, at the Board of Trade and at the International Bureau of Weights and Measures, in France, that the Yard was still changing in length, and that it was contracting at the rate of one part in a million in 30 years, which is equivalent to about one-millionth of an inch per annum. Observations made this year indicate that this rate of contraction is being maintained.

The International Prototype Metre

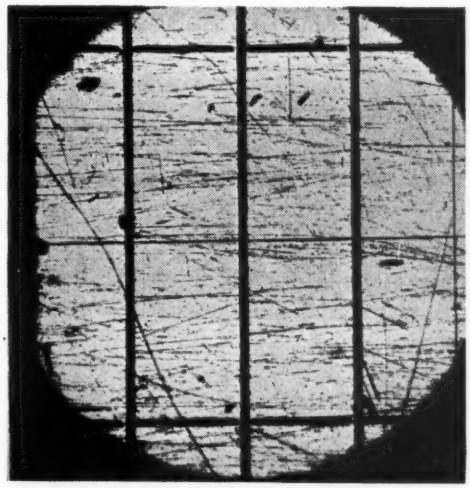
We then come to the International Prototype Metre, in which the neutral plane is exposed along the whole length of the bar, and it is on this plane that the defining lines are ruled at either end. This standard, made of platinum-iridium, was established in 1889 to replace the earlier Mètre des Archives, and at that time it was declared to be within one-thousandth of a millimetre of the size of the previous standard. The platinum-iridium bar is a satisfactory standard because it has been measured in terms of a natural constant, the wavelength of light, on nine occasions since 1892, and in relation to the wavelength of light it has not changed at all. Since there has been a change in the relationship between the Metre and the Yard, and we know that the Metre is stable, it must be the Yard which has changed over the years.

Finally, there is the modern end-standard of steel in which the end surfaces are optically flat and parallel and are so good that you can use this kind of standard in interferometers and measure the length directly in terms of light waves.

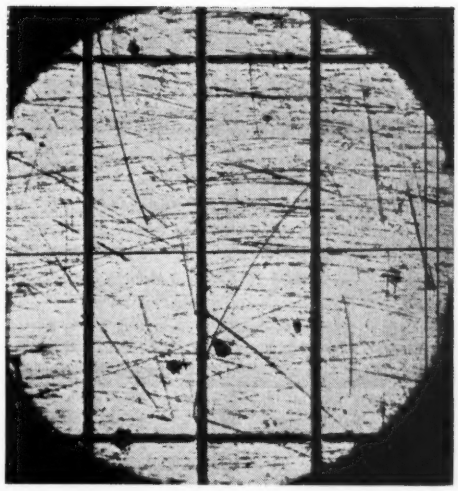
Fig. 11 shows magnified images of the lines ruled on the Imperial Standard Yard. The distance between the horizontal lines in each photograph is about $\frac{1}{50}$-in.; the portion of the central vertical line intercepted between these horizontal lines in each pattern is the defining line.

Fig. 12 shows the corresponding lines on the British copy (no. 16) of the Metre. These are ruled on platinum-iridium and are not so clean as those on the Yard because of the burr thrown up when the ruling is carried out on the harder material. Those portions of the vertical defining lines (A and B) intercepted between the two thicker horizontal lines, which are 0.2 mm apart on the standard, are used when making visual settings under microscopes.

Fig. 3 in the Paper shows the microscope comparator which is used at Teddington for work on the national and other important standards of length. It consists of a double water bath in which the standards are immersed. When used for the national standards of the yard, which we do not immerse in



Line 0 in.

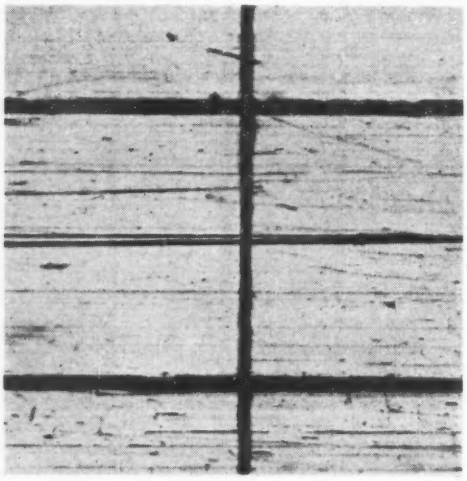


Line 36 in.

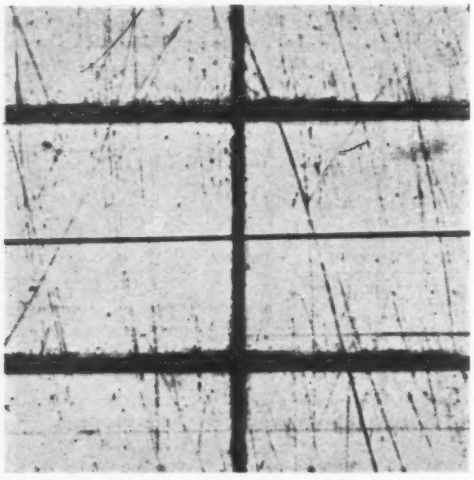
Fig. 11. The pattern of defining lines ruled on the gold plug at each end of the Imperial Standard Yard

water because of the delicate construction of the inserted gold plugs, only the outer bath is filled with water. The metre standards, however, can be immersed in water and we thus obtain a more certain knowledge of the temperature of the comparisons. The standards are set side by side on girders which are adjustable so that the lines can be brought into focus under the micrometer microscopes. The actual precision obtained in the settings on the lines is given in the Paper. A pair of travelling cross-wires under control of the micrometer is set so that it falls symmetrically about the magnified image of the defining line.

In all we make 64 observations of lengh by means of two observers during a complete comparison of two line-standards, and an accuracy of about four millionths of an inch is finally obtained with the best standards. That is about the limit; it has only been achieved at the expense of a good deal of work in ascertaining what are the systematic errors of observation and in devising procedures to eliminate them.



Line A



Line B

Fig. 12. The pattern of defining lines at each end of Metre no. 16, as originally issued in 1889

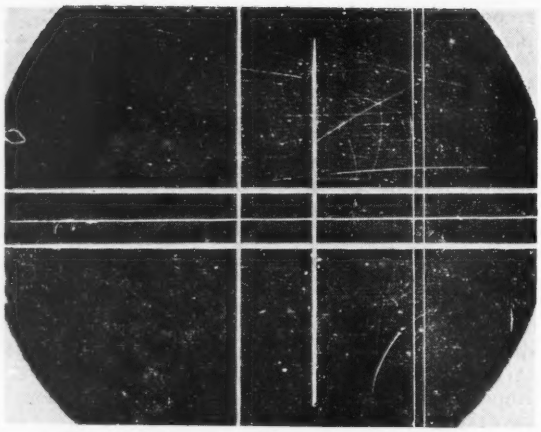


Fig. 13. The pattern of defining lines at one end of Metre no. 16; the two thicker horizontal lines are 0.2 mm apart, while the thinner horizontal line and close pair of vertical lines constitute the graticule of the setting micrometer

Fig. 1 in the Paper shows one end of the British copy of the Metre which has recently been re-ruled with high-quality lines of very much greater precision and fineness than the earlier ones (cf. Fig. 12).

In Fig. 13 is shown a picture of the improved lines we now have on our national copy of the Metre. The two thicker vertical lines are 0.173 mm apart and represent respectively the defining lines at one end of the bar for the 20°C length (the longer line) and the 0°C length (the shorter line). The picture was taken by means of a special camera miscroscope, and we are now considering eliminating the visual method of observation and using one or other of two impersonal methods so that we can get rid of the personal errors of observation.

One method is to take a photograph of the lines and then examine the picture with the aid of what we call a micro-densitometer. It is a sensitive instrument which uses a fine scanning slit of light that is traversed across the images of the defining lines, and the light passing through the photographic plate is detected by a photoelectric cell connected in a logarithmic electronic circuit so that both the change of photographic density across the lines and the gradient of the density can be indicated and recorded.

Fig. 14 shows the density and density gradient traces for the two lines shown in Fig. 13. The dotted line represents the change of photographic density and the full line the variation of density gradient. This impersonal method gives, at the two peak positions of density gradient for each line, a fair

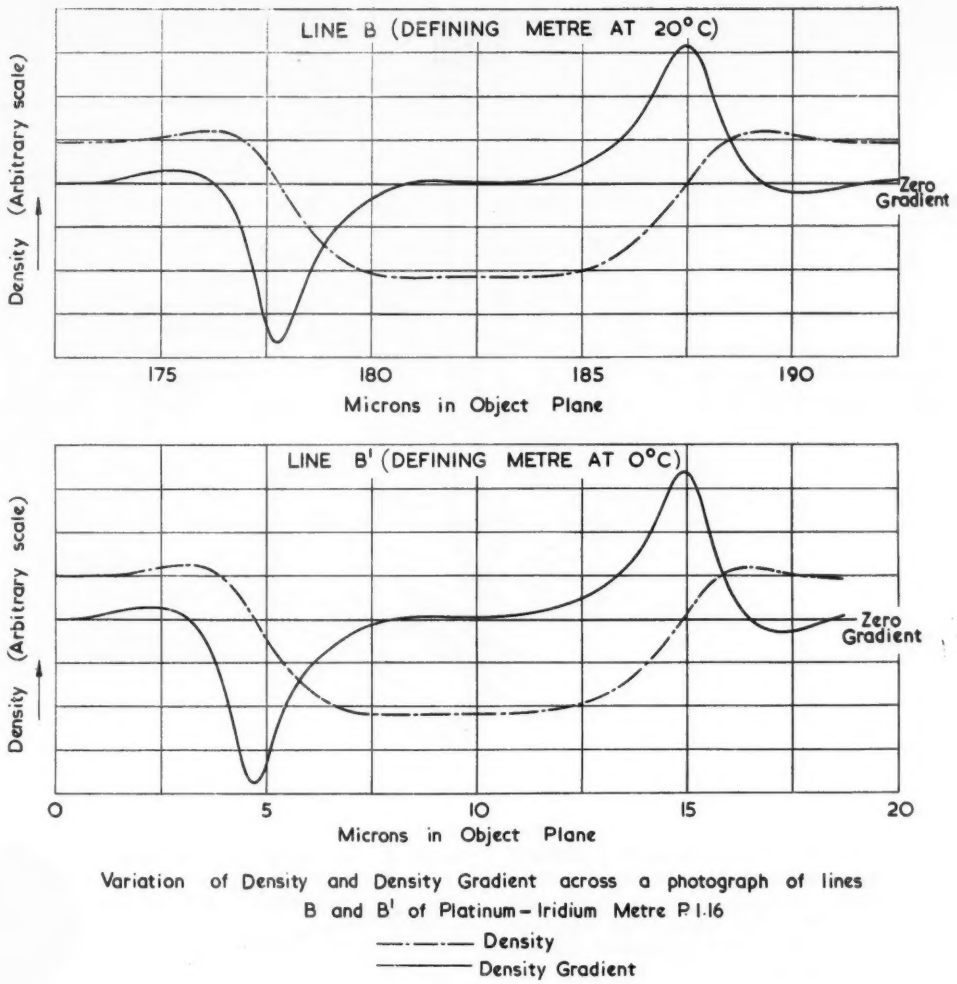


Fig. 14. Variation of density and density gradient across a photograph of the 20°C and 0°C lines on Metre no. 16

indication of what the eye regards as the boundaries of the line, but much more precisely. We have found that from a single observation of this kind we can ascertain the mean position of the line to something like two millionths of an inch. By taking several photographs we hope eventually to get a precision of something like one one-millionth of an inch, or possibly better, in the comparisons of line-standards.

In the second impersonal method we use a photoelectric microscope in which the eye has been replaced by the photoelectric cell (Fig. 15). If the image of the defining line is caused to oscillate symmetrically about the slit S, the impulses being received by the photoelectric cell P are at exactly twice the frequency of the oscillator. The frequency discriminator is arranged so that it only takes account of any component of the received frequency which is at 90 cycles per second, so that when the the image is symmetrically scanning the slit, no frequency of 90 cycles per second is left and the microammeter G reads zero. With this method we find we can make settings to the order of one-millionth of an inch.

I omitted to mention earlier that the length of the Henry VII Yard is within $\frac{1}{32}$-in. of the Imperial Standard, and that of the Elizabeth I Yard is within one-hundredth of an inch of the present Yard, despite the fact that at some time, while it was still the official standard of the country, it was broken and subsequently repaired by means of a dovetail piece.

I want now to say a few words about, and give a demonstration of, the wavelength standard of light. Light consists of waves. The wave theory of light was developed during the early years of the 19th century

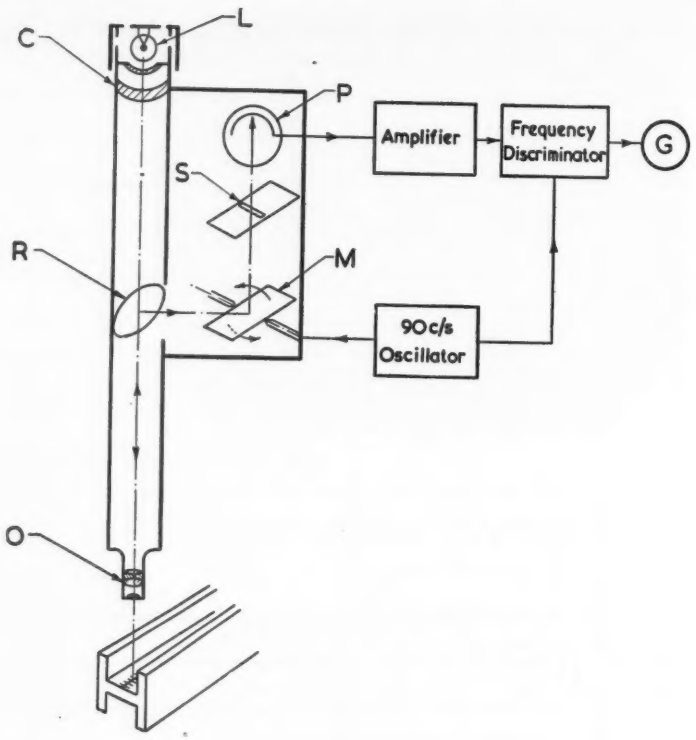


Fig. 15. Diagram of the NPL design of photoelectric microscope; M is a mirror oscillating at 90 c/s

and, in fact, in 1829, the French physicist J. Babinet suggested that the wavelength of light would make a very suitable natural standard of length. It is rather interesting to note that it has taken from that time until now to obtain international agreement to bring this suggestion into practice.

You will see in Fig. 16 diagrams relating to some of the phenomena I shall demonstrate. In order to produce interference of light one makes use of mirrors with thin reflecting films so that they partly transmit and partly reflect light. One system uses parallel mirrors with a convergent beam of monochromatic light yielding a series of concentric circular fringes (fringes of constant inclination) ; and the second system uses inclined mirrors with a parallel beam, producing a pattern of straight, parallel fringes (fringes of constant thickness).

The apparatus used for the demonstrations is shown in Fig. 17.

The interferometer can be arranged in two ways, namely, (a) parallel mirrors, convergent light, to give fringes of constant inclination; and (b) inclined mirrors, parallel light, to give fringes of constant thickness.

(*Dr. Barrell then gave a demonstration illustrating the principles of interference.*)

Such interferential methods have been used for the last 60 years or more, first of all to measure our existing standards of length (the Metre and the

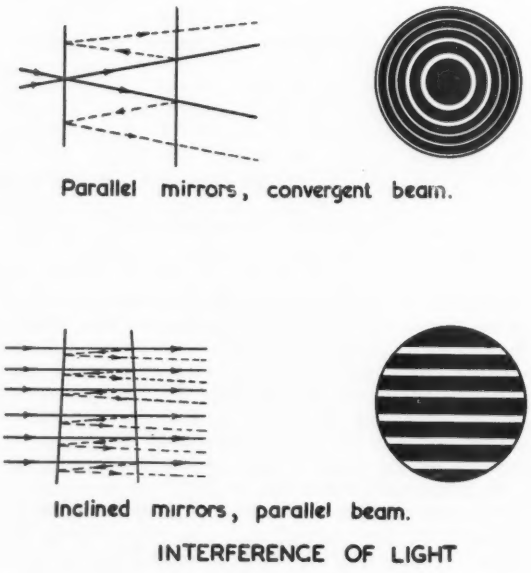


Fig. 16. Interference of light — parallel and inclined mirrors

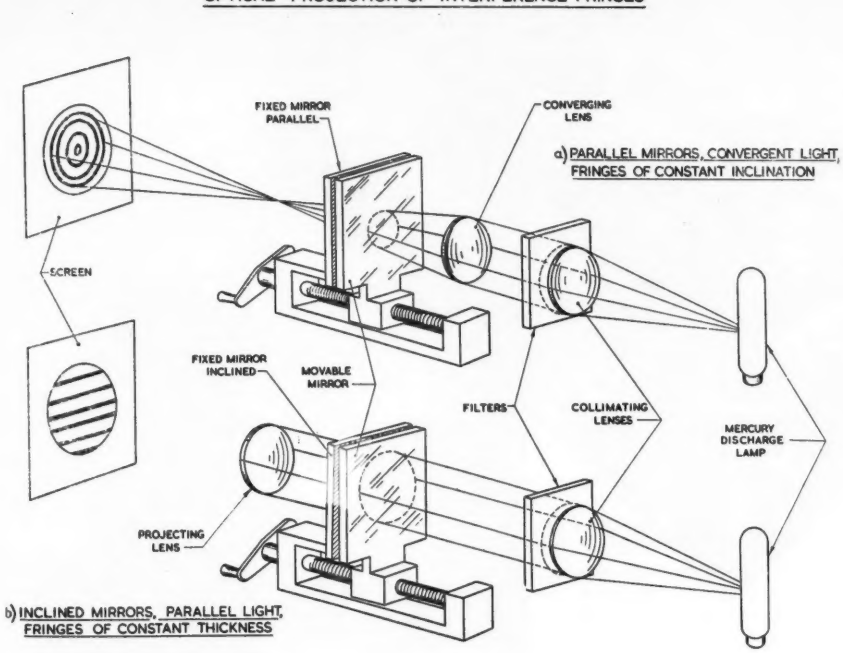


Fig. 17.
Diagram of interferometer for projection of interference fringes

Yard) and the apparatus used at the National Physical Laboratory for this purpose is shown in Fig. 18. Even with the best source of light in the world one cannot measure the whole yard or metre in one operation, and a process of optical multiplication must be employed, starting from a simple fraction of the fundamental unit.

Fig. 19 shows the collected results of the measurements of the Metre, starting from those made by Michelson and Benoît in 1892 - 1893 and ending with those made in the U.S.S.R. in 1940. The variations between the individual results for the Metre are no greater than would be expected from the uncertainties of definition of the material standards.

Improved sources of light

I have already mentioned that new and improved sources of light have been devised, particularly since the War, because of the great amount of work done in atomic energy researches. It was found that if one used pure isotopes instead of ordinary elements, a purer light is obtained. The reason is that in the ordinary elements, such as mercury which contains seven different isotopes of mercury, there are atoms of slightly different masses which affect the physical properties (but not the chemical properties) so that a complicated radiation is obtained from them compared with the purer radiation which is obtained from a single isotope. By using a kind of alchemy in reverse, the isotope of mercury of atomic mass 198 is produced by taking gold, putting it in an atomic reactor, and allowing the gold to be irradiated with neutrons ; the gold then becomes partly radioactive for a short time and then disintegrates, changing to a stable isotope of mercury (mercury-198) which can be distilled from the gold and put into water-cooled lamps where it is excited by means of high frequency oscillations, as in the lamp shown on the lecture bench.

Fig. 2 in the Paper strikingly demonstrates the difference between the isotope of mercury and ordinary mercury when used as a light source, the interference fringes in green light from mercury-198 being ideally simple compared with the complexities of the same light from ordinary mercury.

Another important element for use as a source of monochromatic light is krypton, which is a very rare gas found in the atmosphere. It is also a mixture of several isotopes and it is possible to separate one isotope — of atomic mass 86 — which can be put into a discharge lamp, like that shown on the lecture bench, and excited. The orange-red radiation from the krypton-86 lamp is the one that has recently been selected to define the metre, on the following basis :-

One metre equals 1 650 763.73 times the vacuum wavelength of the orange-red radiation of krypton-86.

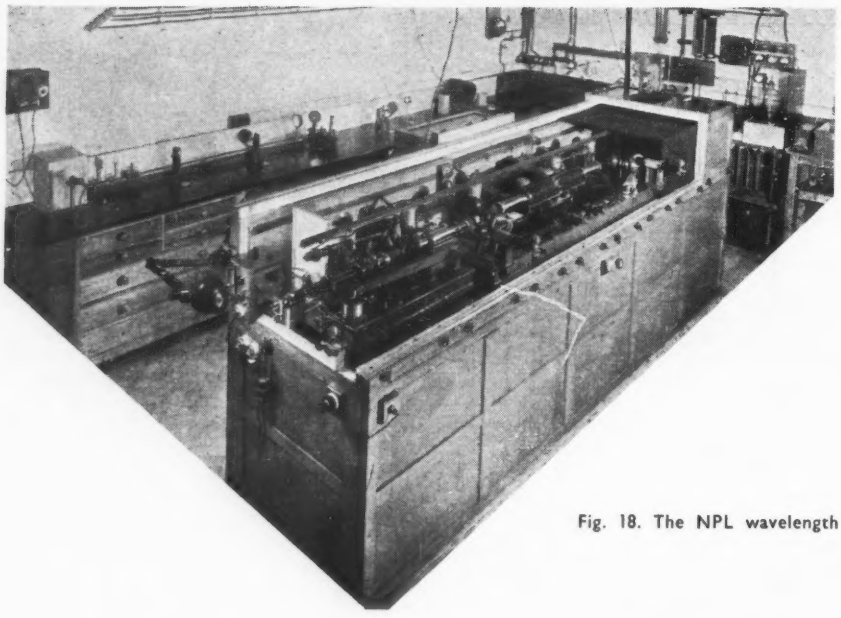


Fig. 18. The NPL wavelength comparator

Date	Observers	Number of wavelengths	Observed − mean	Wavelength (unit = 1 x 10−10m)
1892-3	Michelson & Benoit (B.I.P.M.)	1 553 164.25	+0.13	6438.4691
1905-6	Benoit, Fabry & Perot (B.I.P.M. & C.N.A.M., Paris)	1 553 163.96	−0.16	6438.4703
1927	Watanabe & Imaizumi (Tokyo)	1 553 164.46	+0.34	6438.4682
1933	Sears & Barrell (N.P.L.)	1 553 163.71	−0.41	6438.4713
1933	Kösters & Lampe (P.T.R.)	1 553 164.29	+0.17	6438.4689
1934-5	Sears & Barrell (N.P.L.)	1 553 163.81	−0.31	6438.4709
1934-5	Kösters & Lampe (P.T.R)	1 553 164.27	+0.15	6438.4690
1937	Kösters & Lampe (P.T.R.)	1 553 164.03	−0.09	6438.4700
1940	Romanova, Varlich, Kartashev & Batarchukova (Lenigrad)	1 553 164.34	+0.22	6438.4687
Mean experimental values		1 553 164.12		6438.4696
Values adopted in 1907 (spectroscopy) and provisionally in 1927 (length measurements)		1 553 164.13		6438.4696

The Yard in Wavelengths of Cadmium Red Light			
1931	Tutton	1 420 209.8 (standard air)	The metre was measured also in vacuum wavelengths from 1933 onwards.
1933	Sears & Barrell (N.P.L.)	1 420 210.74 „ „	
„	„ „ „	1 419 818.24 (vacuum)	

Fig. 19. The Metre and the Yard in wavelengths of cadmium red light

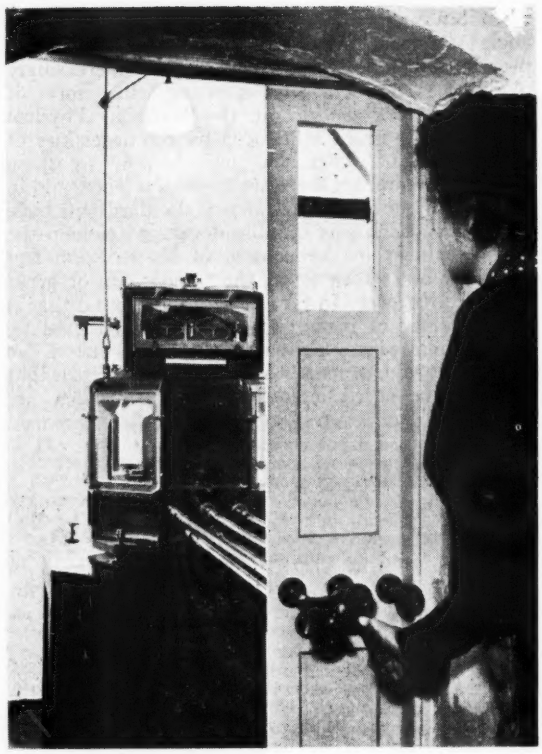


Fig. 20. The precision balance installed in a vault at the NPL, showing how the balance is manipulated by means of remote mechanical controls

Such will very probably be the new definition of the metre in three years' time.

Fig. 4 in the Paper shows the particular kind of interferometer which is used for the determination of slip gauges for calibration and reference purposes. This instrument is the result of a combined effort between the National Physical Laboratory and the firm of Hilger and Watts. It is based on the design of a prototype developed at the National Physical Laboratory and has been very successful, having been bought by other national laboratories and by gauge-making firms at home and abroad. It is capable of measuring every slip gauge up to 4 in. in length to an accuracy of the order of one-millionth of an inch.

(*Dr. Barrell then briefly described the standards of mass and the precision balance used at the National Physical Laboratory for weighings of the highest accuracy.*)

The precision balance is set up in an old wine cellar in Bushy House so that it is maintained at a steady temperature (Fig. 20). The balance is so sensitive that two kilogramme standards of high quality can be compared to one-millionth of a gramme, which is equivalent to one part in a thousand million. Until recently this was one of the most accurate physical measurements which could be made, but such an achievement is now easily surpassed in the comparisons of frequency standards.

Measurement of time

Time is measured by means of clocks, and there are several kinds of phenomena which can be used as "clocks". There are the motions of the astronomical bodies, such as the revolution of the Earth about the Sun giving the year, the revolution of the Moon about the Earth giving the lunar month and the rotation of the Earth about its polar axis giving the solar day. The motions of other heavenly bodies may also be used as timekeepers, such as those of Mercury and Venus and, I suppose, of the Russian Sputnik, although I understand that this last would not be a good timekeeper because it is gradually spiralling back to the Earth and its period of revolution is becoming less.

Oscillations of the balance wheel of a watch or the swings of a pendulum are used as a means of measuring time, but for scientific purposes the mechanical clocks are being superseded by quartz clocks. These consist of quartz ring-crystals maintained in oscillation by electro-mechanical means. They make good standards when maintained under constant operating conditions, although owing to the fact that they have to be associated with electrical circuits it is not possible to contemplate replacing the maintenance of time through astronomical observations by means of the quartz crystal. But it is a very important link in the scheme of maintaining time, especially since the development of the so-called atomic clock, in which the natural periodicities of atoms are used as a means of measuring time. In fact, the first atomic frequency standard to be used to keep check on the astronomical determinations of time was set up at Teddington by Dr. Essen and Mr. Parry in 1955, and it is being daily used to standardise the frequencies of the quartz clocks. The time signals broadcast from the Royal Greenwich Observatory through Rugby are derived from the astronomical observations, and these signals are compared with the indications of a group of quartz clocks the mean frequency of which is in turn compared with the atomic frequency standard. It is now possible to make comparisons between the atomic and the quartz standards to one part in ten thousand million. This is equivalent to a precision of one second in 300 years. The Russians have made an atomic frequency standard which is claimed to be good for one second per century, so we are up on them in that respect!

Fig. 21 gives a general view of the caesium frequency standard.

Fig. 6 in the Paper illustrates the variation in the rate of rotation of the Earth relative to the caesium standard. The graph shows that the Earth is rather a poor timekeeper from the scientific point of view, for in June and July the period of rotation is 60 milliseconds longer than it is in October. Such variations are considered by astronomers and geophysicists to be mainly of meteorological origin.

You will see in the Paper that I have dealt not only with the standards of length, mass and time (and frequency), but also with those of angle, force and hardness.

Although it may appear to many of you that some of the degrees of accuracy to which I have referred are a bit out of the ordinary run for production or precision engineering, it is quite clear that the millionth of an inch is interesting to the production engineer because we are continually being asked to calibrate slip gauges to that accuracy. So far as angle standards are concerned, calibrations to a precision of one second of arc are increasingly required and, generally speaking, the sort of standards work we do at the National Physical Laboratory is much influenced by the necessities of industry. But, of course, in addition to these industrial necessities there are those of science, and in the case of the atomic frequency standard you have something which was actually developed to help the radio engineer in the control of his emission frequencies, but which is, at the same time, of great interest to science. In fact, it is usually found that if the certainty of measurement can be increased by one decimal place, a great deal of new knowledge is gained of the processes of nature, and in turn that leads to novel technological resources which are bound to be of interest to the production engineer.

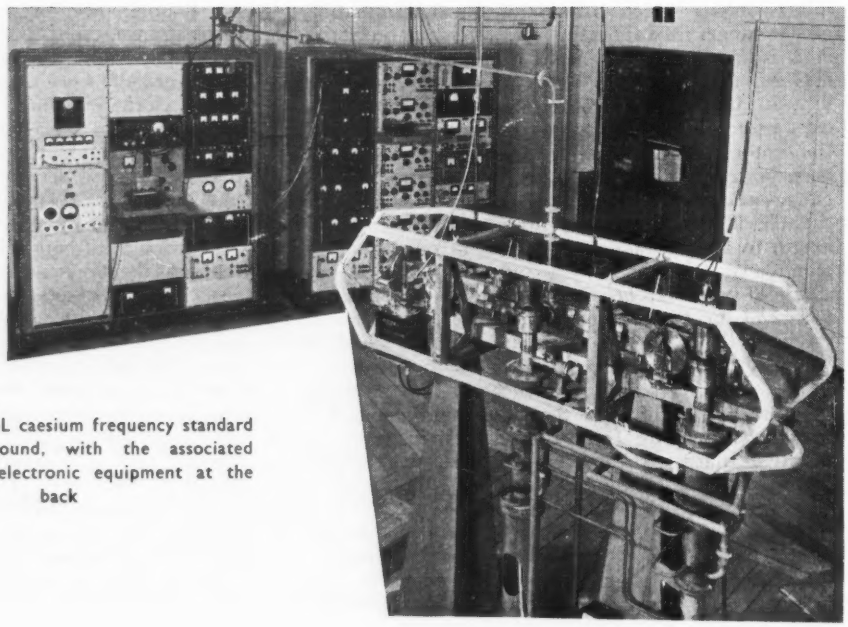


Fig. 21. The NPL caesium frequency standard in the foreground, with the associated electrical and electronic equipment at the back

DISCUSSION

Dr. F. H. Rolt, O.B.E., said that it was indeed a privilege to be asked to open the discussion for quite a number of reasons. One was the fact that he had had the honour of presenting the first Sir Alfred Herbert Paper, which was on a rather similar subject. The second was that the present Paper had been presented by a colleague of his, Dr. Barrell. They had worked together at the National Physical Laboratory for some 30 years, and being very familiar with the work which Dr. Barrell had been discussing, Dr. Rolt could say that he had made an excellent job of it.

The Paper had been read in a lecture room which had heard many scientific papers, and although it had been addressed to a body of engineers, it was really a Paper of a scientific character and the setting was very appropriate for it. The very beautiful experiments which had been demonstrated on interferometry also fitted the surroundings.

There was one point in connection with the date which had occurred to him. Dr. Barrell had said that the present Imperial Standard Yard and Pound were set up by the Weights and Measures Act of 1856. What a pity the Paper had not been presented a year earlier so that it could have marked the centenary of that Act!

The late Mr. J. E. Sears, who was Superintendent of the Metrology Division of the National Physical Laboratory before Dr. Rolt, spoke at the presentation of the first Sir Alfred Herbert Paper, and prefaced his remarks by saying that he thought he was in a rather disadvantageous position to comment upon the Paper because he knew a good deal about the subject. Dr. Rolt felt in the same position on the occasion of the sixth Sir Alfred Herbert Paper! He did not propose to comment much on the Paper itself but rather to make a few general remarks about measurement, and perhaps to try to tie up some of the points in Dr. Barrell's Paper with the practical side of the work of production engineers.

Weights and measures

The question of weights and measures had been a subject which had interested humanity from the very beginning. It entered into every aspect of life, and without Governmental regulations in regard to a system of weights and measures, there could be no communal life at all. Yet it was very surprising how one came to take for granted some of the everyday things of life. When a person bought a pound of butter, a gallon of petrol or a yard of cloth, he was always quite certain of getting his full measure. But did he ever ask himself why that was? There was no policeman behind the counter. The answer was that it was the Board of Trade which was enacting the law of the land. It enforced the law which stipulated that a yard was so much and a pound was so much, and through its weights and measures inspectors the Board of Trade ensured that the man in the street received his due. The day had long since passed when the shopkeeper bought his goods on one particular measure and sold them to his advantage on another. It was equally a far cry from the days of Edward II when "three barley corns round and dry" made one inch!

Another interesting point was that whether a housewife bought a yard of ribbon or her husband was making machinery to ten-thousandths or hundred-thousandths of an inch, both operations were based on the same standard — the Imperial Standard Yard. It was the standard for selling linen or drapery and the standard for engineering purposes although the accuracies of the measurements concerned were, of course, very widely different in the two cases.

On the question of accuracy, and particularly accuracy in engineering work, we were all very conscious of the ever-increasing demands being made upon the production engineer and the gauge-maker for higher accuracy. One had heard, for example, that a number of American engineering firms had recently put up substantial sums of money in order that the Bureau of Standards might improve the accuracy of measurement of slip gauges to something in the region of one-ten millionth of an inch. At first sight that accuracy seemed fantastic, but it was worth recalling that for many years past it had been possible to buy reference sets of slip gauges which were guaranteed accurate to $\pm$ two millionths of an inch. That was the makers' guarantee. Therefore, one would expect a testing authority, which had to see whether those slip gauges were within two-millionths of an inch or not, to be in a position to work to one millionth of an inch, and possibly something finer. That was probably in the minds of the American firms who were putting up the money.

Only 10 days previously Dr. Rolt had been in the United States and had visited the Bureau of Standards where he had discussed the project. He found that the scientists there were undertaking that work very open-mindedly, and were examining the various aspects of it to see the possibilities. They had not finished the job yet, but on asking one of their scientists what conclusions he had come to so far, he was told that they felt that they had a pretty sure grip of measurements to a millionth of an inch: how much further they could go remained to be seen.

Incidentally, one of the slip gauge interferometers which Dr. Rolt had seen at the Bureau of Standards was of British design and manufacture, and he felt confident that it was helping the Bureau to solve their problems. He also saw one of these instruments in another Government Establishment in Washington, where they were also very pleased with it.

Whilst the present Imperial Standard Yard had been in existence for something over a century, it was within his lifetime that engineers had really been able to get a grip of the accuracy which, one might say, was inherent in that standard. That bar simply defined the length of a yard, and things would be greatly simplified if every piece of work which had to be made was just one yard long. The trouble was that engineers had to measure in inches and small fractions of inches, and that was where a great deal of practical difficulty had been in the past. What was the actual length of an inch? True, it was the exact thirty-sixth part of a yard, but how was one to divide the Imperial Standard Yard exactly into 36 parts? That was one of the difficulties which had been experienced for many years, and it was not until after the First World War that it had become possible to subdivide the yard into inches and fractions to any great accuracy. Credit must be given to Mr. Johanssen who, at the beginning of the century, offered the world sets of slip gauges in inches and fractions, but it was nearly 20 years before the National Physical Laboratory was able to criticise those gauges to a suitably high accuracy.

The "Enfield inch"

Many present would remember that in the First World War there was what was known as the "Enfield inch", which Dr. Rolt believed was in error by three ten-thousandths! Things had changed since then, however.

Apart from that particular inch, there had been other appreciable changes in the value of the inch used by engineers during the last 40 years. In 1920, for example, the National Physical Laboratory, as a result of making an improved type of length bar up to 36 inches, came to the conclusion that the values which they had been accepting for their earlier bars were erroneous by 12 millionths per inch, and issued a statement that the Laboratory was altering the accepted values of its standard gauges by that amount.

About 10 years later, in 1931, an International Agreement was arrived at that all engineering parts would be made

to size at a temperature of 20°C or 68°F. As this country had previously been working on 62°F for such parts, it meant that our "engineering inch" had to be changed once again, this time by about 36 millionths of an inch.

Unfortunately, that was not quite the end of the story about the engineers' inch in this country. If, at the moment, the National Physical Laboratory measured a slip gauge and gave a certificate to the effect that it was a true inch, and that same gauge were then sent to the Bureau of Standards in the United States with a request to measure it, the reply would be that the Bureau of Standards found it to be about four millionths away from an inch. That obviously meant that the American value of a standard inch was different from the British, due to the fact that the American yard was different from the yard in Britain by about four parts in one million. That difference was quite significant when it was remembered that, both in the United States and in this country, some sets of slip gauges were being made to within ± two millionths.

Importance of temperature

It was true that this question of unifying the British and American yards had been discussed for many years, and it would be interesting if the author could state how long he thought it would be before it would be settled. Dr. Rolt still hoped that it would happen in his lifetime.

It was desirable, in his view, to say a word about temperature. The title of the Paper was "The Bases of Measurement", and he felt that the basis of temperature measurements might well have been included in it, for the simple reason that the standards of length had to be defined in terms of certain temperatures. Temperature was one of the most important factors in the sphere of measurement in his view, and he would have liked the author to have included something about it. For instance, what was a temperature of 20°C? Where did it come from? What was the scale of temperature behind it?

Concluding his remarks, Dr. Rolt suggested that he honestly felt that the whole question of the various influences of temperature in engineering workshops on the accuracy of measurement would be a very good subject for a field research by the D.S.I.R. He was certain that if further advances were to be made in practical engineering measurements, it would have to be in the direction of a much closer observance of the influence of temperature.

In a written contribution subsequent to the meeting, Dr. Rolt says:

I should like to add the following remarks to the comments which I made in person during the meeting on 31st October.

I believe it was Sir Joseph Whitworth who, a century or so ago, first stressed the importance of the flat surface as one of the essential requisites, or bases, for accurate measurements. The truth of this statement will, I am sure, still be vouched for by all concerned with the making of accurate engineering measurements. In fact, it is generally well understood that the accuracy to which a length measurement can be made largely depends upon the degree of perfection of the flat surfaces which bound either the object concerned, or the measuring appliances used, or in many cases, both.

Surface plates, with their flat surfaces, serve literally as a base for many diverse types of measurement. Flat surfaces are also essential features in the faces of micrometers, gap gauges, slip gauges, angle gauges, precision polygons, the base plates and optical surfaces of interferometers — to name but a few examples of their prevalence in the sphere of measurement. Let us not forget either that the precision of definition of the primary units of length, the yard and the metre, depends upon the perfection of certain lines scribed on metallic surfaces, and this in turn is largely influenced by the flatness of those surfaces.

All in all, the flat surface would appear to call for inclusion amongst the bases of measurement which Dr. Barrell has mentioned in his Paper.

Turning to another point, Dr. Barrell has mentioned the application of wavelengths of light and of radio microwaves in the millimetre range of wavelengths to linear measurements. I should like to ask Dr. Barrell if any work has been done to make similar use of infra-red and other radiations having wavelengths in the region between optical radiations and radio microwaves. Is it possible to generate radiations in this intermediate region with a degree of 'purity' comparable with the optical radiations from mercury and krypton isotope sources?

I ask these questions because the possibility of using radiations with accurately known wavelengths of the order of say 1 mm., 1/10th mm., and 1/100th mm., might well find very useful applications in the measurement of large jig and gauges for such purposes as aircraft construction, and of large engineering components in general.

Dr. Barrell (left) with Mr. G. R. Pryor, Vice-President of the Institution; Mr. H. G. Gregory, Chairman of Council; and Sir Walter Puckey, Past President, at the reception preceding the meeting

Mr. J. Loxham (*Managing Director, Sigma Instrument Co. Ltd.*) said that the Paper contained a large amount of unique and highly technical data presented in an interesting and condensed form. With the wealth of knowledge and information at Dr. Barrell's disposal it was rather a pity that he had not expounded some of the sections in greater detail. In the very interesting discourse which he had given he had largely corrected that omission, but it would be unfortunate not to put his unique and very valuable knowledge on permanent record. For example, many persons would no doubt be very interested to obtain from the author a little more information about the process which was used to produce the Mercury Isotope 198, which was used to give the remarkably clear lines shown on the interferogram illustrated in Fig. 2 by the neutron irradiation of gold in an atomic reactor.

Like Dr. Rolt, he wondered whether Dr. Barrell would care to summarise the developments likely to take place in the future, and which were mentioned in his Paper, by giving his opinion on when there would be that very desirable condition of an internationally universal basis for length measurement, and a value for the yard/metre relationship which was recognised throughout the world.

It would also be of value if Dr. Barrell would explain what occurred when each of the five plug gauges illustrated in Fig. A were pressed into the common ringe gauge shown on the diagram. That simple experiment had already been carried out by Dr. Barrell and it threw some light on the extent to which plug and ring gauges could be used as a basis for measurement.

It was gratifying to see that Dr. Barrell opened his Paper with a quotation from Lord Kelvin. That quotation contained much wisdom and was worthy of careful study by the production engineer. Mr. Loxham desired to add two further quotations — one made about 100 years before Lord Kelvin's quotation, and the other made about 100 years later. The first quotation was from an entry in the diary of an English engineer, Richard Reynolds. It was dated October, 1760, and read as follows:-

" Began this day to scour the bore of a great cylinder of a fire engine for drawing the water from the coal pit at Elphinstone, of a bore 28 in. across, and in length 9 ft., the same being cast of brass and after much discouragement, and the spoiling of three before, which made us of much doubt if we could ever succeed in a task of such great magnitude; but being by reason of the extremity to which the Proprietors of the pit were at, having to employ more than 50 horses to discharge the water thereof, we were much urged to persevere, and we give great gratitude to Almighty God, who hath brought us through such fiery tribulations to an efficient termination of our arduous labours.

"Having hewed two balks of deal to a suitable shape for the cylinder to lie therein solidly on the earth in the yard, a plumber was procured to cast a lump of lead of about three hundred weight, which being cast in the cylinder, with a dike of plank and putty either side, did make it of a curve to suit the circumference, by which the scouring was much expedited. I then fashioned two iron bars to go around the lead, whereby ropes might be tied, by which the lead might be pulled to and fro by six sturdy and nimble men harnessed to each rope, and by smearing the cylinder with emery and train oil through which the lead was pulled, the circumference of the cylinder on which the lead lay was presently made of a superior smoothness; after which the cylinder being turned a little, and that part made smooth, and so on, until with exquisite pains and much labour the whole circumference was scoured to such a degree of roundness as to make the longest way across less than the thickness of my little finger greater than the shortest way; which was a matter of much pleasure to me, as being the best that we so far had any knowledge of."

The industrialist's approach

The second quotation is by Sir Ben Lockspeiser, until recently Secretary of the Department of Scientific and Industrial Research. In 1950, he said:-

"The rapid scientific advance of the past fifty years has been accompanied by a parallel growth in the application of science to industry, and in this century the scientist's attitude towards measurement has spread largely to the industrialist. And for a very good reason; for if the industrialist is unconcerned with verifying theories, he is very much concerned in verifying what he is making and, more than this, in controlling the technological processes in manufacture. Modern quantity production depends on stage by stage control and systematic testing, which can only be accomplished by means of measuring instruments. Not so very long ago the use of instruments in industry was regarded as something of a luxury. Today there are few industries that can afford to forego the advantage of measurement and instrument control. In a highly developed technological industry, like that of oil refining, instruments alone can account for 10% of the capital outlay on plant. This is at present exceptional, but it is not likely to remain so, for the economic future of the country will depend, to an increasing extent, on the elimination of avoidable waste in the use of materials, and the production of goods of higher and higher quality."

In support of what Sir Ben Lockspeiser had said Mr. Loxham added that from experiments which he had made, he could say with absolute certainty that when the science of measurement was used to control an engineering production process, and especially when that process was fully automatic, very valuable and highly important benefits became immediately available.

It might be interesting to take the basis of measurement as provided by Dr. Barrell and as illustrated in the tables on pages 9 - 10, and see how that very convenient basis of measurement could be used in commercial engineering organisation.

The set of reference blocks described in the Paper had, for a period of about six years, provided its owner with a basis of measurement which was accurate to one-millionth of an inch. When reference blocks of that accuracy were used in conjunction with an instrument of the type illustrated in Fig. B, it was possible to calibrate secondary sets of blocks to two-millionths of an inch. Those secondary grade reference blocks calibrated as described might then be used with the same instrument for the routine calibration of shop sets, and if the reference blocks being inspected were of good geometric shape, the accuracy of calibration could be kept well within four-millionths of an inch. Those sets of reference blocks could now be used in the Shop Inspection Departments and in certain circumstances adjacent to precision grinding and similar machines, and when used with simple mechanical instruments of the type illustrated, the workman on the factory floor was provided with the means whereby he could measure the parts he produced to an accuracy well within ten-millionths of an inch. That was immediately possible, and it was unfortunate that so very few engineers took advantage of this simple technique.

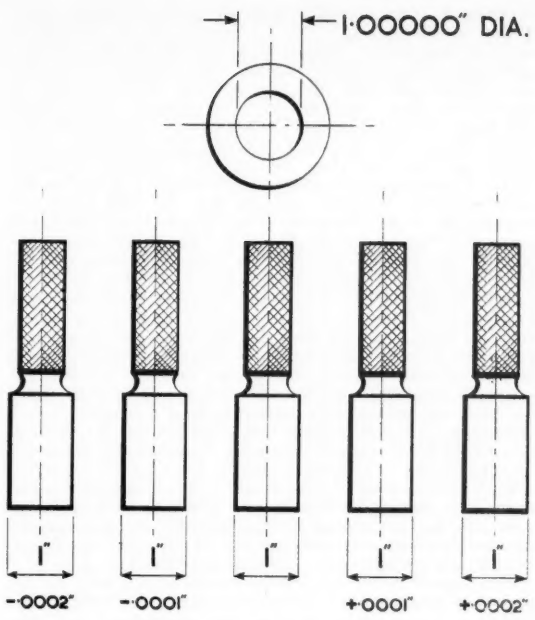


Fig. A

If a similar diagram had been prepared of internal measurements showing the equipment used for declaring the size of internal diameters and using the same reference blocks as a basis, the record would not be so good, and he suggested that the problem of declaring the size of a high precision ring gauge was one of industry's most urgent requirements. It was to be hoped that Dr. Barrell and his colleagues would continue their experiments in an effort to solve this important problem.

Finally as was seen from published data, in a span of about 200 years man had advanced from a situation where the basis of measurement for the production engineer had changed from the thickness of his little finger to a few millionths of an inch. It was surely recognised by all production engineers that from a technological standpoint we live in very exciting times. That was especially so when it was realised that the great advances of the past were still taking place, and it was his carefully considered opinion that if the facilities which were immediately available, and likely to become available in the very near future, were used to the full, it should be possible within the next five years to produce parts to tolerances of about a quarter of those now in use in current practice in this and other countries.

Dr. Barrell, in reply, referred to the question of the value of the yard raised both by Dr. Rolt and Mr. Loxham, and said that it was agreed in the British Commonwealth and in the United States that the yard should be defined as the fraction 0.9144 of a metre. That was the same as 1 in. (1/36 yard) equalling 25.4 millimetres exactly, this inch being described as the unified (or international) inch. In fact the present American inch was about two parts of a million greater than that. In order to maintain a stable basis for measurements in terms of the yard for scientific and industrial purposes (though not for the statutory purposes of trade as regulated by Weights and Measures legislation) the National Physical Laboratory used the value of the yard in terms of the metre as determined in 1922 (see Paper). The corresponding value for 1 in. (1/36 of Yard in 1922) was 25.399 956 mm, which is about two parts in a million lower than the proposed unified (or international) inch. Thus, by accepting the unified value neither the British Commonwealth nor the United States lost much face, because it was almost half way between the present values. It was now up to the law makers. Agreement had also been reached on the technical side on a common value for the pound, because there again the values had slightly departed from one another but not to the same extent as for the yards.

The point raised by Dr. Rolt in connection with temperature was a good one, and it might perhaps have been wise to have added a small section on temperature. But the Paper already ran to some 10,000 words and this was enough for anybody to be asked to read!

With regard to internal measurements and the American project to measure block gauges to one ten-millionth of an inch (and also to make them to that accuracy), if one was to be able to state that a certain block gauge was accurate to one ten-millionth of an inch, then its form had to be accurate to about that same order. It would certainly have to be flat and parallel to the order of five ten-millionths of an inch, which was over five times better than required in existing specifications for slip gauges. It was also necessary to improve on the stability of the gauge. British gauges had a very good record in that respect. It was believed that industry at the moment was not very interested in the Laboratory trying to push the limits of measurement of slip gauges to the ten-millionth of an inch. There was the far more important question of transferring from parallel slip gauges to round work, and at the moment the accuracy with which holes could be made and measured was certainly not such that slip gauges accurate to one-millionth of an inch were a cause of uncertainty, and certainly those of an accuracy of one ten-millionth of an inch were not at present necessary. The National Physical Laboratory preferred to study the method of applying standards of length in the form of slip gauges to the improvement of internal measurements, and particularly internal diameters. In recent years internal diameter measuring machines had been devised, using an auto-collimator and a special standard built up from slip gauges, which covered a range of 0.1 in. up to 6 in. to an accuracy of 0.000 01 in.

It was very interesting to learn from the quotation from Richard Reynolds that the little finger was used as an ovality gauge!

Dr. C. Timms (*Mechanical Engineering Research Laboratories*) referred to control mechanisms and the need for very accurate measurement of angular motion, and said that in certain mechanisms it was desirable to have means

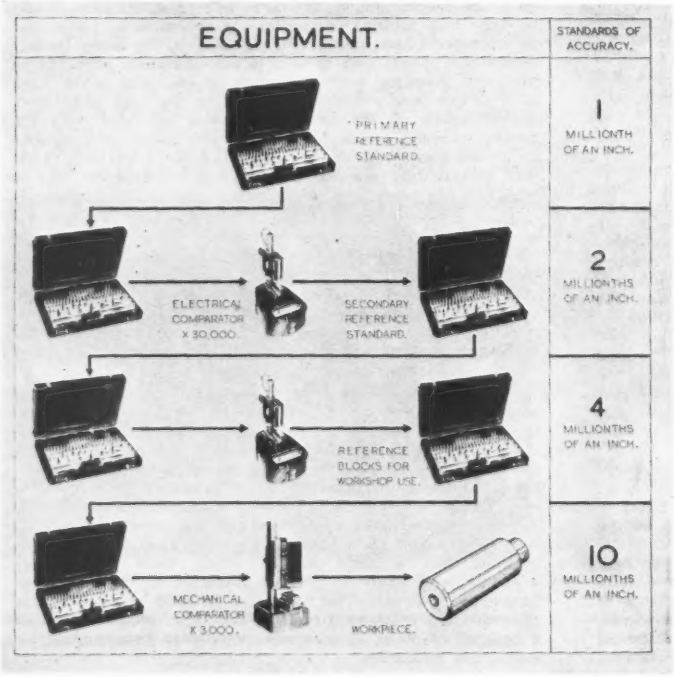


Fig. B

of controlling accuracy to the order of a second of arc. One could quote instances of precision gears of 20 in. diameter in which the divisional tooth by tooth should be of the order of ten-thousandths of an inch, which was equivalent to two seconds of arc. That was approaching the fundamental accuracy with which the National Physical Laboratory was dealing at the present time, and it would be interesting to know whether Dr. Barrell was carrying out further research on this important subject.

Dr. Barrell, in reply, said that his views on splitting the second of arc were the same as those on splitting the millionth of an inch. As an example of what one second of arc represented, if one viewed a halfpenny three miles distance away it subtended at the eye at an angle of one second of arc. Experience with regard to physical standards of angle such as the Tomlinson angle gauge and the precision polygon, particularly the latter, showed that they could in the limit be measured to an accuracy of the order of 0.5 second of arc using the autocollimator. It would probably be possible to extend the accuracy of measurement to the order of one-tenth of the second of arc by using interferometric methods, but it was necessary to improve the standard itself before such extremely high accuracy could be applied.

With regard to circular division, colleagues in the Light Division of the National Physical Laboratory say that even with the best circle using a number of microscopes symmetrically distributed around the circle to take account of the eccentricity, a second of arc was in their view about the limit which could be obtained.

Dr. J. C. Evans (*National Physical Laboratory*) said it was his job to try and provide standards for the engineering industry, and the difficulty which he encountered so very often was in connection with the question of form. Dr. Barrell had dealt with the measurement of angle and had referred to form in general terms. Had his Paper been not one dealing with the bases of measurement, but rather with the application of standards of measurement to industrial purposes, no doubt he would have made a big point of form.

Dr. Barrell had, in his reply, pointed out that if one were going to measure a slip gauge to one ten-millionth of an inch, that is, to something between five and ten times the diameter of a molecule, it was necessary to have the form right. It was the question of form which ultimately determined the precision with which the measurements could be made at the Laboratory. As Dr. Barrell had pointed out, the question of measuring angle turned ultimately on the perfection of the two surfaces which bounded that angle. Another way of looking at the second of arc was by stating it as being the angle subtended in New York by Cleopatra's Needle!

Mr. Loxham had shown that starting with a slip gauge, the size of which was known to one-millionth of an inch, he could, by means of comparators, proceed through 2 and 4 to 10 millionths of an inch. It was presumed, however, that he had block gauges up to four-millionths of an inch but had then surreptitiously slipped in a cylinder. That meant changing from parallel to cylindrical form and different compression effects were being introduced. Although it was possible to calculate them, there was no certainty about the magnitude of those effects when talking about one-millionth of an inch. That was why it was more important to take up the suggestion made by Mr. Loxham that attention should be devoted to measuring holes more accurately.

Mr. K. J. Hume (*Education and Training Officer, Dowty Group*) said that, having read and heard the Paper and the subsequent discussion, he was very proud that he had made the suggestion to the Papers Committee that Dr. Barrell should be asked to present the sixth Sir Alfred Herbert Paper.

The point which so many people made, namely, what was the use of such measurement, had been fairly thoroughly expounded by the author and subsequent speakers. It should be realised nowadays that in any field of technology it was always as well to have as much up one's sleeve as possible. That applied to length, time and probably to weight measurement.

There was a table in the Paper which showed the results of the metre determination in terms of wavelength, and of particular interest was the closeness of the first determination of 1893 to the subsequent determinations and the mean. It was most remarkable that earlier workers did so well as they had in view of the experimental apparatus available to them.

It would be interesting to learn why the two National Physical Laboratory results were distinctly low in comparison with others. Secondly, although there had been a great improvement in definition and clarity when using isotopes of mercury and other materials, had the author or others reached a point where they could detect the spread of monochromatic light even when using isotopes?

Dr. Barrell, in reply, said that the fact that earlier workers round about 1900 obtained very nearly the same results as the later ones in the light-wave measurements of the Metre was solely due to the fact that all were using a natural standard which was reproducible to that sort of accuracy. It did not matter what method was used as long as the experiments were conducted in a proper way.

The reason why the measured number of wavelengths in a metre varied from laboratory to laboratory a little more than might be expected was that none of those who had claimed to have measured the Metre had in fact measured the Metre itself, which was a bar very carefully preserved in a vault in a suburb of Paris. The Americans, British, French, Germans, Japanese and Russians worked with various national copies of the Metre. The accuracy with which the metre length was defined by the Prototype Metre and its copies was of the order of two-and-a-half parts in ten million. It would be found that the spread of results given on the list shown was somewhat less than three parts in ten million, and was thus very little greater than the uncertainty in the measurement of the distance between two defining lines on a bar. The difficulty was to find the centre-distance between two lines which were each about 20 wavelengths in thickness. It was pure chance that the National Physical Laboratory's values happened to be low whereas other people's were higher, for the total range of variation among the nine determinations was no more than would be expected in the circumstances just described.

As to the spread of radiation, one of the reasons why the expert Advisory Committee recently decided that the krypton-86 lamp was the best source to use as a means for the future definition of the metre was that the krypton lamp could be run at a temperature of only 60°K above absolute zero — or about 230°C below normal temperature. It was capable of maintaining a discharge at that low temperature. The atoms moved about in all directions at velocities depending on their absolute temperature and mass; in a gas which was being excited such motions could be resolved partly in the line of sight and partly across it. If an atom moved within the line of sight, the frequency was changed owing to the Doppler effect, so that the lower the temperature and the higher the mass of the excited atoms, the less the spread of frequency, and so wavelength. The mercury-198 lamp could not at present be excited satisfactorily at those very low temperatures and was therefore less satisfactory, despite the higher mass of the mercury atom.

Mr. Frisby said it was probably fair to say that engineers were more concerned with relative errors than with absolute errors. It would be a waste of time and money to measure to a greater accuracy than one one-hundredth of an inch. Bearing in mind the main concern of economics, speed and simplicity, it would be of interest to have the author's views on the controversy concerning the question of the metre and the yard. Did Dr. Barrell feel that in time to come Britain would go over to the metre?

Dr. Barrell, in reply, said that, speaking as a scientist, Britain should in his view go over to the metric system; but he realised that, particularly for industry, it was going to be a very difficult matter. Like the United States, Britain was very advanced in methods of production. All the

Some of the standards displayed in the exhibition. They include end-bars incorporating a new type of screwed connection, a 72-sided polygon, standard hardness blocks, the NPL-Hilger gauge measuring interferometer, proving rings incorporating improvements recently developed at NPL and a model of the NPL 50-ton deadweight standard machine for calibrating elastic proving devices

machine tools and raw materials were denominated in terms of inch units or pound units, and it would be 20 years of absolute hell if the recommendations made by the Hodgson Committee * were followed that this country should go over to the metric system, using the suggested change-over period of 20 years. The decision made by the Government was that this country should not go over to the metric system, but that both the yard and the pound should be expressed in terms of the corresponding metric units.

* *See reference* 5 *in Paper.*

There was a great deal of discussion now about the Free Trade Area which Britain was officially very anxious to join, and all the other nations of Europe used the metric system. The metric system could, of course, be used in Britain if desired. It was perfectly legal, but it would be a different kettle of fish if it became obligatory. There was no doubt that trade between the United Kingdom and the Continent would be easier if weights and measures were common to both. Last year India decided to go over to the metric system and it was estimated that it would take a period of 15 years. It would take 15 years in the case of an under-developed country such as India which had no

established system of production such as in Britain. India had a population of about 400 millions, and there would be a great market in the future for British exports. If India were going over to the metric system it would be easier to carry on trade if Britain did so also. China was definitely going to make the metric system obligatory. There was an estimated population of 630 million in China, and here again the question of export trade was of supreme importance to us. It was a case where Britain would, in the next few years, find it necessary, in the words of Mr. Dulles, to make an "agonising reappraisal" of metric versus Imperial measures, and the longer the decision was delayed the more difficult it would be to make the change.

Sir Walter Puckey (*Past President of the Institution*) said that earlier in the day a meeting of the Council of the Institution of Production Engineers had taken place, and at a certain stage in the proceedings, a certain Past President of the Institution found himself robbed of his vote! That came as a great shock to that particular person, because with the arrival of the bright young fellows who were taking the place of the elders on the Council of the Institution, a Past President very soon came to realise that his authority was not what it was. He had thought, however, until this morning that he was still left with the responsibility of a vote.

But tonight all was different and he had regained his vote, and was indeed honoured in being able to propose a vote of thanks to a distinguished speaker. He felt certain that production engineers present had been fascinated by the presentation given by Dr. Barrell and by the contents of his Paper. Production engineers knew how difficult it was for them to measure more accurately in their own works, but when one read of the painstaking and skilful work conducted by the author and his associates over many years, and realised the great work involved in moving a standard of measurement one decimal point, one was filled with admiration and realised how much pioneer work was going on in the backrooms of Britain so that production engineers could turn out better goods.

No doubt there were many visitors present in the gathering and he felt sure that Dr. Barrell would not mind if he used the occasion to dwell, perhaps, on the broader problems and possibilities inherent in the Sir Alfred Herbert Paper. The President, in his opening remarks, had referred to that late great President of the Institution, Sir Alfred Herbert, and mentioned his liberal outlook. One of the things which the Council had tried to do was to provide within the scope of the Sir Alfred Herbert Paper a range of subjects which were truly representative of the liberal outlook of Sir Alfred Herbert himself, and at the risk of being slightly facetious — which he certainly was not — he reminded the visitors that on the occasion of the sixth Sir Alfred Herbert Paper, extreme accuracies in the possibilities of measurement had been reached, and in the possibility of applying these to materials and machines. It might be desirable to remind visitors on such a great occasion that the scope of the production engineer was one which included not only materials and machines but also men. Previous Sir Alfred Herbert Papers had attempted — not without some success — to broaden the scope of discussion, and to try to get a measure not only of materials and machines, but also of men.

Speaking on a personal note, he was occupied at the present time with many problems which affected men and management, and there were times when he had a sense of frustration which arose from, on the one hand, listening to the sort of Paper which Dr. Barrell had presented and, on the other hand, realising that the bases of measurement used in trying to assess more accurately the qualities and size of men were full of inaccuracies, ambiguities, and basic research possibilities. Therefore, one could not help wondering whether there might be in the future some greater collaboration between scientific effort, money and time spent on the sort of problems demonstrated by Dr. Barrell, and carrying them over into the sphere of man himself, and measuring more accurately the possibilities inherent in man, so that the production engineer might be given a more complete set of tools than hitherto.

Under the ægis of the Sir Alfred Herbert Paper, there had been three Papers which had developed the scientific approach to man, and it was to be hoped that sooner or later they might come together to measure more accurately right across the production engineer's job. It would certainly be interesting to hear Dr. Barrell and Dr. Grey Walter talking about "Interferometry"!

It seemed only a short time when he was present, five years ago, to hear Dr. Rolt give the first Sir Alfred Herbert Paper. Five years later there was a "slip off the old block" in the form of another distinguished member from the same stable. He hoped that Dr. Barrell would feel very satisfied by his performance, and it was only necessary to look round the lecture theatre to realise that the dream of the theatrical manager had almost been achieved, of "packing 'em into the aisles". It was a great tribute to Dr. Barrell's drawing power and an even greater tribute was that so many had stayed until the end.

On behalf of every one present, it was with much pleasure that he proposed a hearty vote of thanks to Dr. Barrell for his Sir Alfred Herbert Paper.

The vote of thanks was carried by acclamation.

Dr. Barrell, in a brief response, said he very much appreciated Sir Walter Puckey's kind remarks. So far as he was concerned, it had been a dream realised to be able to lecture in such a famous theatre as that of the Royal Institution. He recalled as a student coming to the Royal Institution to hear such eminent men as Lord Rutherford, Sir Joseph Thomson, Sir Arthur Eddington, A. A. Michelson, and other famous scientists and engineers, and to see them at this bench. After a lapse of nearly 40 years The Institution of Production Engineers had made it possible for him to realise this dream of being able to lecture in the Royal Institution, for which he was very grateful.

In a written contribution, received subsequent to the meeting, **Mr. L. W. Nickols,** M.I.Prod.E., *makes the following comments:*

In his Paper, Dr. Barrell mentions the difference in length between the United States Yard and the Imperial Standard Yard, a difference which leads to the U.S. inch being about 4 millionths of an inch larger than the British inch. The proposal to redefine the yard in the British Commonwealth and the U.S.A. on the basis, 1 in. = 25.4 mm exactly has already been made legal in Canada, with the result that we now have three separate inch units in the world today; what, for convenience, we may term the U.K. inch, the U.S. inch, and the Canadian inch, which falls about half-way between the U.K. and U.S. inches.

The difference between these inch units is of importance not only to manufacturers of length standards of high qualities, but also to manufacturers of large engineering components made to small tolerances. For example, in BS.1498 : 1954, Gear Hobbing Machines, a tolerance of 0.0007 in. is quoted for the cumulative pitch of a feed screw which is 36 in. long. If the actual pitch error of such a feed screw were measured in the U.S.A., then it would differ from the actual pitch error measured in the U.K. by about 0.000 15 in., an amount which is significant in relation to the tolerance on the feed screw.

Incidentally, the example of the feed screw may be used to illustrate the effect of temperature on the measurement of large dimensions, to which Dr. Rolt has drawn attention. Even assuming that the feed screw and the length standard used in the pitch measurement have identical coefficients of expansion, a difference of only 1°C between the temperatures of the standard and feed screw at the time of measurement would result in the introduction of an error of about 0.0004 in. into the measured value of the pitch error.

THE ENGINEERING GRADUATE—

a Production Problem

by L. J. Kastner,

M.A., M.Sc., M.I.Mech.E.

Professor Kastner was educated at Highgate School and Clare College, Cambridge. Before going up to the University he began his apprenticeship with Davies and Metcalfe Ltd., locomotive engineers, of Stockport, and returned to them after graduation.

In 1938 *he became Osborne Reynolds Research Fellow at Manchester University and, later on, Lecturer and Senior Lecturer in the Engineering Department there. In* 1948 *he was appointed Professor of Engineering at University College, Swansea (University of Wales), and since* 1955 *has been Professor of Mechanical Engineering in the University of London at King's College. His chief research interest is in unsteady flow phenomena.*

Professor Kastner is a member of various committees of the Institution of Mechanical Engineers, and has served on its Council.

I TAKE it that any methodical solution of a problem in production requires that answers must be found to a number of questions, amongst which the following seem to me of primary importance :-

1. What do you want to produce ?
2. What materials are available to you ?
3. What are the limitations on the processes you adopt and on the staff you employ to do the job ?
4. To what tests will you subject the product ?
5. Are the quality of the product, its suitability for its purpose and the numbers produced constantly under critical review ?

I am not suggesting that this list is comprehensive. I believe, however, that there must be many cases where clear and satisfying answers to the above questions would be of the greatest value, and the production of the engineering graduate, a problem on which the spotlight of nation-wide publicity is now turned, is in my view a case in point. Moreover, in the field of education it seems to me that experts are often rather prone to look at and to discuss their problems as a whole, when it might sometimes be more advantageous to try a different approach and to break down these problems into their component parts. Consequently, I now propose to try to find answers to the five questions set down above, where the overall problem is that of producing engineering graduates whose present performance and future promise will satisfy the nation's needs, and will enable us to compete, on better than equal terms, with the best the foreigner can do.

The qualities a graduate should have

I begin by asking myself what are the qualities a graduate should have ? This apparently innocent question involves one straight away in all the difficulties of choosing a criterion. In some fields, perhaps, such a choice is relatively straightforward. For example, in the study of thermodynamics we often conceive an ideal process or an ideal engine with which to compare real processes or real engines, and such conceptions are on the whole simple to grasp and not too hard to apply. But the conception

of the ideally-qualified human being for a particular kind of endeavour is a very different matter, and very much open to argument. Nevertheless, as a basis for discussion, let me make some suggestions.

First, the ideal graduate must be a man of integrity — by which I mean much more than mere honesty in the narrow sense of the word. Irreproachable honesty, of course, intellectual as well as moral, we expect from every educated man and on the whole I think it is not often that we are seriously disappointed. But what is not so common is the willingness in a man to do more than he is paid for, the capacity to accept responsibility and to act with initiative, and the attitude of mind in which it is unthinkable to ask — or to order — others to do more than one would do oneself.

Second, I would place the ability and the desire for independent thought. I believe it was Einstein who once said "Imagination is more important than knowledge". In nearly all walks of life, the man of real imagination is the man from whom improvement springs: he is the innovator, the pioneer. Therefore, I have placed the special quality he possesses higher in my list than the power and determination to work hard over long periods, perhaps without any recognition or special reward. The capacity for sustained hard work can, I think, be cultivated by nearly everyone and is probably the most powerful weapon in the armoury of the man of middling talents. It is astonishing how often it opens the way to the very highest positions, and I place it third.

Backing up these three major qualities, there should be others of what I would call secondary merit and which I do not think can be placed in any particular order — a sufficient but not an excessive ambition; energy both physical and mental; moral courage; an instinct for what is socially proper; a capacity for quickly establishing good relations with others; a good appearance and address. No doubt there are other qualities which are often desirable, but I suggest that an employer would usually be satisfied if a candidate for a post in his organisation could score high marks under each of the headings I have mentioned.

It would, nevertheless, be folly to attempt to produce any kind of uniformity. Engineering graduates will, by and large, have to take their places in complex organisations, and within such organisations it is a blending of the special qualities of differing individuals which makes for success. The late Lord Trenchard once said that the Royal Air Force could make use of "the scholar and the craftsman, the linguist, the organiser and the mechanic, the poet and the Philistine, and even the crank", and declared that this brought about "clash of opinions and it is from clash of opinions that progress results". Perhaps not all organisations could usefully employ so wide a variety of types, but the moral still holds good.

The raw material available

In discussing the raw material available, I ought to begin by remarking that my academic experience has been confined to University Engineering Schools. Nevertheless, I think that much of what I shall say under this heading is applicable to other institutions of broadly similar character. In the main, candidates for places in the University Engineering Departments fall into three classes, namely: (a) those applying direct from the sixth forms of schools, and desiring to enter at about 18½ years of age (or two years older if they elect first to do National Service); (b) those who have left school having secured the necessary examination qualifications for University entry, but who intend to spend a year in industry before embarking on a degree course; and (c) early school-leavers who have spent some few years in industry and have made use of the facilities which exist for part-time technological education in order to reach the necessary academic standards.

Necessity for discrimination

As things are today, the total number of qualified applicants for places may very often be much in excess of the number of places available at a particular University or College; though, taking the country as a whole, there seems as yet no evidence of an overall shortage of places. In an engineering school of good reputation, therefore, it is often necessary to discriminate between candidates by some means or other, and it is here where difficulties at once arise. An obvious, but not a very satisfactory, means of discrimination consists of comparing the marks obtained by the candidates in some form of qualifying examination which might be the G.C.E. at Advanced Level in appropriate subjects, or a special supplementary examination. Whilst a good pass should be insisted on, it seems to me unrealistic invariably to prefer one candidate to another simply because the former has averaged 10% more than the latter, provided each is comfortably above the pass line. Since we desire to obtain the very best material, we must devise some additional form of test, and in general this test is based on an interview.

It is the object of this interview to find out as much as possible about the prospective student, and consequently it is very necessary to enlist the aid of others beforehand so as to have a basis for one's questions. A letter from a headmaster, or an employer, is of the utmost value, and in my experience is nearly always unbiased and in most cases is carefully and thoughtfully written. Very occasionally there are exceptions — I recall a letter I once received from the headmaster of an important school: "So-and-so is a nice boy and a keen footballer. Although now 18 years of age, he is still in the fifth form. I think he would make an excellent engineer. Yours faithfully, ———". But even that letter is not uninformative and tells one something significant both about the boy and about his headmaster!

When the interviewer and the applicant are face-to-face, the former should be quite clear about the aims of the interview. In the present context I suggest that these aims might be to find answers to the following questions:-

1. Are the applicant's appearance, character and personality such as to inspire confidence?

2. Is there good evidence that he possesses an ardent desire to study engineering ?
3. Does he show any signs of real aptitude for engineering, and of ambition to succeed as an engineer ?
4. Has he a lively mind and plenty of interests outside the field he desires to study ?
5. What are his strong and weak points, as revealed by the interview, and can any glaring weaknesses, academic or otherwise, be quickly corrected ?

Creating a good impression

I am inclined to think that a candidate's appearance, at an interview which he knows to be important, is often — but not of course invariably — a pretty good guide to his quality. A young man who is neatly dressed and who is not overdue for the attentions of the barber creates a good impression at the outset, and it is surprising that this elementary fact is frequently overlooked. It is undoubtedly true that untidy appearance does not always signify an untidy mind (and many men of quite exceptional quality bear witness to this), but very often I believe that untidiness on an important occasion is the outward sign of a fault of character which it may be impossible to eradicate, and which in commerce or industry may be a serious handicap.

The candidate's personality, I believe, must declare itself to some extent through his speech. But only to some extent — the interviewer should beware of hasty judgment passed on a candidate who may at first be tongue-tied in unfamiliar surroundings. Nevertheless, if the young man is really sincere in his desire to become an engineer, the interviewer should be able to find evidence of this quite quickly, though it is much less probable that he can determine with any certainty whether or not the candidate has an aptitude for engineering. Indeed, I consider that one should be extremely cautious in one's search for an answer to this latter question, and that any answer is likely to be incomplete, or even useless, unless the true meaning of the question is fully understood.

For example, it is still true that in the minds of a number of people aptitude for engineering is considered to be inseparable from the desire to handle tools and manipulate machinery, but in the vast field which is covered by modern engineering there is room for many people who have never felt this desire and who, indeed, may rise to the highest positions in spite of this. Consequently, the interviewer must bear in mind a whole range of desirable aptitudes, and should try to check the candidate's powers under each of a number of headings. Aptitude tests, therefore, unless framed with the utmost care, may well be dangerously misleading and may even allow some very fine fish to slip through the net.

Ambition to succeed

A reasonable and proper ambition to succeed is, I suggest, a quality without which a young engineer cannot hope, in a competitive world, to get very far and I judge it very important to enquire (probably indirectly) whether a candidate has this quality strongly developed. For if he has, I am predisposed in his favour. It is unlikely that he will disappoint me and he will usually do better than those to whom nature has been more generous in other directions. but who lack a disciplined driving force to direct their energies.

One of the criticisms often levelled against the engineer is that he is too single-minded, too absorbed in his own work, and consequently too ignorant of the events and ideas which occur in other spheres of life, to be a good citizen of the modern world and that this fault disqualifies him from achieving complete success in the higher managerial and directorial fields in which others, who claim to have a wider and more liberal outlook, are said to have a distinct advantage. There is, I think, still some force in this criticism, though I hope not as much as there used to be. I believe that some of the young men (although of course not all) entering the engineering profession today are the equals of the best entering any other profession, and at an interview for a place in an engineering school some attempt should be made to enquire into the general interests of the candidate. This, in fact, is not at all difficult and two or three minutes' general talk about the books and newspapers a candidate reads, about his hobbies, his membership of school societies, the way in which he spends his holidays, and so forth, is usually most revealing.

Conducting the interview

From a properly conducted interview, a great deal can be learnt about a candidate's strong and weak points. If the interview is arranged to take place between, say, six and nine months before the beginning of a session, there is still a fair chance of correcting any obvious academic weaknesses. Attention can be drawn to other points of significance, and the co-operation of a candidate's headmaster or employer be sought. A candidate may perhaps be advised to stay another year in school, if this is possible, or he may be told that he would benefit greatly from a year in industry before commencing full-time academic study of engineering.

Thus one may conclude that the interview, taken together with an academic record and a headmaster's report, is a reasonable and a fair way of judging an applicant who has passed, or who is expected to pass in the near future, the necessary qualifying examinations. It does not always, however, lead to the desired result and failures at the end of the first or second year of study are not, regrettably, as uncommon as they should be. It is hoped by improved techniques to reduce the number of these failures, but as yet there seems no certain way of recognising the applicant who has reached his intellectual ceiling, nor the one who has the best of characters at school but who as an undergraduate constantly refuses to put his back into his work.

The limitations of the teaching process

Having, as we hope, awarded the places which are available to the most promising candidates, we have to decide what subjects are to be taught, what teaching processes are to be employed, and what kind of men the teachers are to be. As to the subjects of study, it is unnecessary to go into much detail except to observe that the choice of these is the result of an enormous amount of thought and discussion. Courses are subject to continual review leading to modification and improvement, and those who are dissatisfied with them must bear in mind the brutal fact that every course is a compromise between the desire to keep up-to-date in subjects the knowledge of which is expanding daily, between the necessity to keep the ground to be covered in three years down to a reasonable amount, and between the determination to give the student a firmly-based foundation in fundamental engineering science. In many cases the subjects of engineering science are now supplemented by auxiliary courses in economics, in law, in management, in the history of technology, and so on, so that the student has no reason to complain of any lack of variety.

The methods and processes used in this country for the teaching of engineering undergraduates are now of quite respectable antiquity. They depend on formal lectures supported by less formal tutorial classes, on regular design classes in the drawing office, and on a considerable amount of laboratory work. In the early stages both drawing office work and laboratory work are fairly closely supervised, but later on the student has full opportunity to exercise his individuality by working on design problems chosen by himself and by embarking on experimental work of a more advanced nature. At this stage consultation with staff is always available, but the student is nevertheless encouraged to work independently to a considerable extent. In the ancient Universities of Oxford and Cambridge, a student will have his own tutor or supervisor who will take a direct personal interest in his work. As residential facilities at other Universities improve, it is to be hoped that a smilar system will be adopted by them, but at present such facilities are exceptional.

Keeping in touch

It is right that our teaching methods should be subjected to a careful scrutiny. Are these methods efficient and do they serve their purpose ? Should more use be made of mimeographed notes ? of so-called " preferred texts " ? of films ? of recorded lectures ? of radio and television ? I doubt if it is possible at present to answer " yes " or " no " to any of these questions. The right solution is only to be found by experiment, and what is preferred at one place is not necessarily right for another. However, whatever methods are adopted it is surely necessary to aim at close personal contact between the teacher and the taught. Many of the subjects of study in the first year of undergraduates' courses are entirely new to the student and he must be introduced to them clearly, sympathetically and not too abruptly. The lecturer must have the gift of ' keeping in tune ', so to speak, with his class, but he cannot afford to adjust his pace to that of its slowest member.

The teaching process in an undergraduate course is thus subject to considerable limitations in regard both to its methods and to its scope. It is also subject to limitations arising from the immense difficulty, under present conditions, of recruiting for Engineering Departments academic staff of the proper status and quality. A little while ago I was the recipient of a sardonic, but not ill-founded, complaint from an experienced and able university teacher who declared that when a professor of engineering advertises for a lecturer he wants a man who is an accomplished teacher, an enthusiastic research worker, and a man of established professional and academic status, having firm contacts both within industry and within the teaching profession, and willing to work 54 hours a week for about £1,000 a year !

Maintaining the quality

Now the fact is that there is a good deal of truth in this. Every engineering professor would like to ensure that his staff consists of men of the highest quality and I assume that industrialists and other interested parties would agree with him. Yet the supply of such men, desirous of making a career in the engineering departments of universities, imbued with the evangelising spirit of the devoted teacher and blessed with the zeal for enquiry of the true research worker, is now reduced to a trickle and, with increasing competition from industry and elsewhere, threatens to dry up altogether. If this is allowed to happen, it will be necessary to fill the vacant posts with men who are not of first-class quality, and the work which can be done by such men is hardly likely to be better than second-rate.

The education of young engineers is now so important that the problem of recruitment of academic staff in applied science warrants, in my opinion, a special study in which representatives of industry might well be invited to assist. Such an enquiry should examine sources of supply, reasons for the present shortage, possibilities of seconding suitable men from industry, and above all those attractions and incentives which are at present inadequate or lacking. It should have as its aim the making of recommendations for bringing an end to the present shortage within, say, three years, so that when better accommodation and equipment is generally available at our engineering schools, it shall be matched by enthusiastic and well-qualified staffs satisfied with their working conditions and proud of the positions they hold.

To achieve this will cost money, but it is after all common experience that if you want something good you have to pay a good price for it. Unless this staffing problem is solved the production of engineering graduates will be subject to a serious and unfair handicap, and those we produce will not be as good as they ought to be.

The testing of the product

In the technology of engineering much thought has been given to the testing of materials which are used in the manufacture of various articles, and to the testing of the finished articles themselves. On the whole such tests are thorough, informative, and not too difficult to carry out and the conclusions to be drawn from their results are seldom seriously disputed. At various stages in his progress towards a degree, the undergraduate must be subjected to certain tests, but since these tests are applied not to a relatively simple inanimate object, but to a vastly complex human being, their nature, their frequency and the results obtained from them are the subjects of lively discussion.

The formal written examination, whether or not supplemented by tests in the drawing office and in the laboratory, is generally accepted in the University engineering departments and in technical colleges as being the best way by which a student's progress, knowledge, and ability may be measured, though the imperfections of the examination system are, I think, everywhere recognised. It is, probably, a measure of this recognition that the number of examinations which the engineering student must undergo is not generally agreed, some authorities considering that one set of examinations per year, taken at the end of the session, is sufficiently, whilst others require two sets, and sometimes there may even be three.

A common pattern

However, whatever may be the number of examinations which the student is required to take, one can detect in most places signs of a common pattern. This pattern requires that in the first and second years of a three-year course, a good proportion of examination questions shall be fairly conventional in nature and shall be designed to test the student's familiarity with his subject and his knowledge of fundamentals, since in the early stages it is essential that a considerable body of information is accumulated and understood. From the first year onwards, however, a few problems of a more searching nature are progressively introduced and at the final honours stage great pains are taken to provide questions which, it is hoped, will be a real test of a candidate's intellectual capacity, power for independent thought, and knowledge of his chosen subject. Such questions are designed to show up the limitations of the industrious man who cannot think for himself and of the able man whose aim is to get through the course with the minimum of study. As the saying goes " The learned man who could not think and the clever man who would not work met in the third class, and they did not like one another ".

If all engineering students were cast in the same mould, a single system of classwork and examination would be sufficient to establish an order of merit. But it may happen, not infrequently, that by the end of a student's first year he has shown himself not to have those special gifts which are necessary for success in an honours course of high calibre, though in the opinion of his teachers he has other qualities which could be most valuable in many branches of engineering.

The proper place for such a man is in a so-called " Ordinary Degree " or " Pass Degree " course where, ideally, a wider field should be covered — though not with the same depth of penetration — than is possible in a Honours course. Unfortunately, it is not always possible to provide proper resources for both " Honours " and " Ordinary " or " Pass " courses, and the Pass degree tends to be regarded as a consolation prize for the student who has failed to obtain Honours. I think this is a very great pity.

Is the product suitable for its purpose ?

Those who undertake the academic training of the engineering graduate do not wish to accept the whole responsibility of judging whether the final product is suitable to play a worthy part in industry, or in some other field where qualified engineers are needed. They know, of course, that at the present time there is a great and unsatisfied demand for the young engineering graduate but they recognise that this demand is, at least in part, a sign that the country is becoming aware of the real importance of engineering and engineers with national economy and is more in the mood to complain that the supply is unequal to the demand rather than to criticise too seriously the quality of those who are available. This is, or ought to be, a temporary situation. At some future time there should be enough young engineers to go round and the prospective employer may then be expected to be more critical and more selective than he is at present.

The prospective employer, in exercising his undoubted rights of criticism and selection should, however, bear two points constantly in mind. The first is that the new graduate is essentially an unfinished product who, in most cases, has not yet received that practical training which in some form or other is a necessary part of the equipment of every professional engineer; and second, that a course leading to a bachelor's degree or its equivalent cannot be (or at least ought not to be) directed towards the needs of a particular industry. Consequently, it is unfair to treat the new graduate as if he were fully fledged : he should rather be regarded as an asset with considerable potentialities which may be invaluable later on, but which are still undeveloped.

Comparison of performance

It is, nevertheless, perfectly just for an employer who has had, during a period of years, a number of graduates in his organisation to look at these men with a critical eye and to draw certain conclusions from their performance. If this were done methodically over a wide segment of industry, some extremely interesting results might be obtained. For example, is the First Class Honours man more valuable than the man who took a Second ? Is the Pass Degree man notably inferior — or is he inferior at all — to either ? Is there any correlation between the class of a man's degree and his salary at age 35 or 40 ? In what respects is the Universty-trained man ultimately better or worse than others who received their technical training elsewhere ? Why are

the products of University preferable (or the reverse) to those from other places ?

What I am suggesting, in fact, is that there should be a regular exchange of information and opinion about these matters between industry on the one hand and the Universities and Technical Colleges on the other. If, for example, it is true that industrialists are not satisfied that they will receive from the teaching establishments, say during the next 10 years, enough men of first-rate quality, then the reasons for this could be freely debated and corrective measures might be taken. Doubtless such measures would take time to have their effect and, very likely, they would cost substantial sums of money. They might, perhaps, involve much more propaganda in the schools than has yet been considered necessary or advisable. They might, indeed, provoke stiff opposition from some quarters.

I am not, of course, suggesting that nothing has yet been done along these lines. Governmentally-organised bodies have issued reports. Individual firms have arranged meetings between their senior executives and persons holding high academic positions. The professional institutions have done much that is useful. But what I think is wanted is a standing committee, with equal representatives from industry and from the academic world, which would keep these problems of engineering education permanently under review. Such a committee, though having no authority to ensure that its recommendations were carried out — and, I would hope, no desire to seek such authority for itself — might be expected to wield great influence.

I chose as my title the words "The Engineering Graduate — a Production Problem". I used these words because I wanted to talk about certain aspects of the task of producing engineering graduates which I think bear a distinct resemblance to the problems which the production engineer faces. Whether or not you agree with me about the closeness of this resemblance, I think it is hardly likely that you will quarrel with the assumption that the problems I have discussed are of importance to all who occupy responsible positions in the wide field of activity which we call engineering. We ought all to take a proper interest in the training of our successors and we should often remind ourselves that the engineering graduate of today is the professional engineer of tomorrow. On his quality and achievements a great deal will depend.

HEAD OFFICE POSTAGE

THE greatly increased postage rates over the last year or so have created a heavy burden on Institution expenditure — for example the first increase, which was made on 1st January, 1956, resulted in additional annual expenditure of £3,000 on postage of the Journal alone!

In order to counteract this, the staff at Head Office is continually exploring new ways and means of affecting economy in postage. Many members, too, are very helpful in the fact that they draw attention to incidents of apparent wastage. In many cases, members refer to incidents where they have received two letters from Head Office in the same post, which they think could have been included in the same envelope, thus making a saving in postage. All these cases are studied very carefully and in some cases apparent wastage could have been avoided. However, it must be remembered that when circular letters are sent to members, the envelopes are addressed on an automatic addressing machine and the cost of labour involved in sorting through these envelopes, in order to include a typewritten letter to be despatched the same day in one particular envelope, would be far greater than the cost of the additional postage used.

Constructive criticism from members in this connection is always appreciated and any suggestions for effecting economy in postage will be most welcome. If you should receive more than one communication from Head Office in the same post, it would be of assistance if you would return the actlal envelopes or wrappings when reporting this matter to Head Office.

THE VARIED APPLICATIONS OF

DRILLING MACHINES

in relation to other production

by W. A. Hannaby, M.I.Prod.E.

Presented to the Halifax and Huddersfield Section of the Institution, 12th December, 1956.

IN presenting this Paper, I will endeavour to trace the development of the drilling machine from its early inception to the application of it today as a general purpose type of machine, as well as a semi-special and special machine covering the demands of automation. I will also give examples of actual installations in various types of factories.

It would, however, be as well, at the outset, to define what is meant by drilling and where this operation ends and other subsequent operations begin. I would say, that in general, drilling could be defined as an operation of producing a hole from the solid material, the maximum diameter now considered economical for such an operation being in the region of 3 in. Above this diameter, the process can be termed boring, or trepanning, where other cutting media are used, such as boring bars, cutters, etc.

Design developments

However, I would first like to spend a short time reviewing the developments which have taken place in the design of the drilling machine since the days of the very early radial and vertical types of machine.

It is, of course, common knowledge that the operation of drilling a hole goes back to the earliest days of mankind, when the drill consisted of a piece of bone and the rotation was obtained by twisting a piece of hide in a bow-shaped instrument: the material being drilled was not, of course, metal. Interesting though these investigations into early historical periods may be, they would not yield any instructive information as far as present production problems are concerned.

I want, therefore, to commence round about the year 1840, for it was in this period that we have the first records of a drilling machine, designed and built by James Nasmyth, of Nasmyth & Gaskell, of Manchester. A model of this machine can be seen at the Science Museum, London, to whom I am indebted for the following information.

"The frame consists of a base with two columns supporting a cross-girder, which carries the drill spindle and its driving and feed arrangements. The power is transmitted through mitre wheels to the drill spindle, which is fed downwards by a central screw supported by a cross-head, carried on two small wrought iron columns, this screw being fitted with a winch handle for feeding it downwards by hand.

"There is also an automatic feed given by a vertical shaft that is intermittently rotated by a pawl worked by an eccentric on the lower end of the spindle sleeve."

This machine appears to be the very early forerunner of the present-day cross rail drilling machine. In Hull Museum there is also a drilling machine built by Whitworth in 1842.

The structure of the cross rail type machine, for the benefit of those who are not cognisant of it, can be described as a beam supported at each end by vertical supports, the drill saddle traversing along the beam, whereas a radial drilling machine structure is a cantilever.

The drills themselves used during this period consisted of a rough bar of steel flattened in the smith's forge and with an angular point forged at one end. These were known as 'spade' or 'diamond' drills. As can be imagined, these drills were very unsatisfactory, because if the holes were of any depth the drills had to be constantly reground as carefully as possible, in order to get them to run true.

However, due to the ingenuity of some person or persons who, I believe, are unknown, a twist drill was developed, this being made by twisting a flat bar of

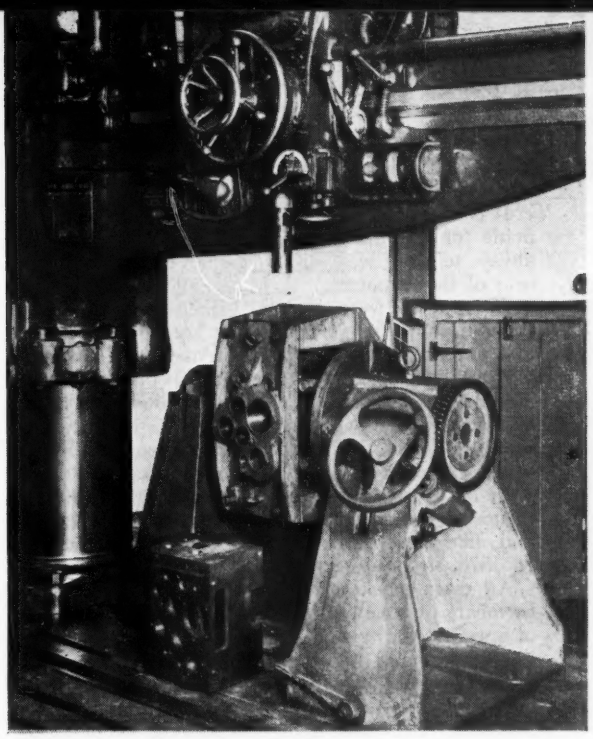


Fig. 1. A radial drilling machine equipped with a rotating fixture for the drilling and boring of a milling machine feed box. The fixture is rotated by means of the handwheel on the right, so as to bring the holes in the different faces of the feed box under the drill spindle. The bores machined vary from $1\frac{3}{4}$ in. to 3 in. dia. Cutting speed is 120 ft./min., for both roughing and finishing. Feeds: .012 in. per rev. for roughing; .008 in. per rev. for finishing. Tolerances: $\pm$.0005 in. for size and centres. Tools used are tungsten carbide tipped, preset in bar. Floor to floor time for boring: 1 hr. 45 mins., plus 1 hr. 10 mins. for subsidiary holes. Holes are first rough drilled, then semi-finish bored, leaving $\frac{1}{16}$ in. on dia. for finish boring.

steel whilst it was hot. For a time these drills existed side by side with the 'spade' or 'diamond' drills. They were still far from satisfactory as they did not clear their own chips, as is the case with the modern twist drill, but broke them up, causing the hole to become clogged.

Round about 1860, twist drills of a design approximating to the modern type were made in the United Kingdom by Sir Joseph Whitworth and a Mr. Greenwood. They were also made in America, and then followed Morse's development in reducing the cutting angle and developing the taper drive to the drilling machine spindle, now known as the Morse Taper. These drills were capable of doing far more work than the spade or diamond drills, or the subsequent twist drills made in the U.K.

These developments had a bearing on drilling machine design, because higher speeds than were possible with the old tools could now be used.

In 1862, the firm of Muir's, of Manchester, were awarded a Prize Medal at an International Exhibition for what was advertised as their 'C' type radial drilling machine, which was claimed to drill up to 6 in. diameter by 10 in. deep. Muir's started business in 1842 as lathe builders, and were awarded a Prize Medal at the Great Exhibition of 1951, for a hand or power driven bench drilling machine.

I was privileged, by the courtesy of the David Brown Machine Tool Company, to see some old records of Muir's, and in 1868, the price of their 'C' type radial drilling machine was £45 12s. 10d.

There was also built a steam drilling machine, the revolutions to the spindle being obtained from the 4 in. stroke of the piston, whose diameter was also 4 in. The stroke drove through bevel gearing and thus to the spindle, and it also had a reversing motion to the revolutions of the spindle.

★ ★

Mr. Hannaby received his early technical education at the Halifax Technical College, gaining the Bronze Medal of the Engineers' Employees Federation. He served his apprenticeship with William Asquith Limited, Halifax, and subsequently progressed with the firm until he was in charge of the Planning Department. He then transferred to the outside staff as Service Engineer and Demonstrator, and was later appointed Sales and Technical Representative for Northern England, Scotland and Ireland.

He joined the Drummond-Asquith (Sales) Limited Organisation in January, 1938, *as Sales and Technical Representative, and was subsequently appointed to his present position of Area Manager.*

Mr. Hannaby, who is the present Chairman of the Halifax and Huddersfield Section of the Institution, and also serves on the East and West Ridings Regional Committee, has lectured in many parts of the United Kingdom. He is a member of the Institute of Engineers and Shipbuilders in Scotland.

It was claimed that this machine would drill up to 1½ in. diameter from the solid, and open out to about 3 in. diameter.

It is rather amusing to note that one of the claims made for this machine was that the foreman could always tell if it was working or not by observing the beat of the exhaust!

These drills were used by Robey & Company, of Lincoln, on the erection of some large sugar machinery; and also by Easton, Amos and Anderson, of Erith, who used compressed air in place of steam. There were, of course, a number of other well-known builders of drilling machines during these periods, such as Shanks, Hetherington, Buckden, Tullis, and others.

In 1865, some 90 years ago, William Asquith commenced business in Halifax as a machine tool builder and, like most others, made all types of machines. In 1878, he produced his first drilling machine.

All these machines were of simple design, driven by means of cone pulleys, with a very limited number of speeds. As the materials used at that time were unable to stand up to high speeds, the number of revolutions per minute was low, and the feed was performed mostly by hand. The drilling machine, however, continued to be considered, as in earlier days, the cheapest means of producing a hole, and the question of the accuracy of the hole was never contemplated on this type of machine. The further operations on the bore in order to obtain accuracy were carried out on other machines, such as engine lathes.

These early types of machines continued in use for many years, and even up to 1905 the belt drive was still general, but a gear box and feed box had then been incorporated, as higher speeds and feeds were now found to be necessary for the application of high speed twist drills.

Development of the electric motor

The development of the electric motor, both the constant speed and particularly the variable speed electric motor, constituted another step forward in design. It was soon appreciated that by substituting a motor for the pulleys by connecting, through a reduction box, direct to the gear box (which due to the use of a D.C. variable speed motor was considerably simplified) the machine could be installed in any desired position without regard to the layout of the existing line shaft. Also, the efficiency of the machine was increased by the elimination of belt slip.

The drive, however, was still by means of the internal vertical shaft, gearing, and thence by cross-shaft before reaching the spindle, and it meant that the radial drilling machine was still far from being the easy manipulative medium it is today.

Following this development came the mounting of the motor on the arm, and I believe William

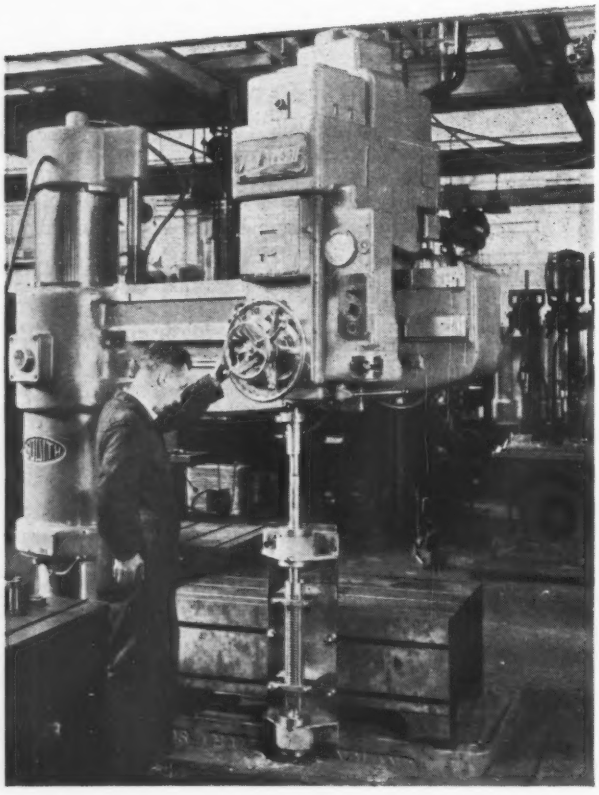


Fig. 2. This illustrates a fine boring application using a standard radial drilling machine, the component being the spindle barrel of an O.D.1. drilling machine. The boring bar was mounted in a hardened steel bush rotating in phosphor bronze bushes, fitted with ball bearing thrust washers to take the feed thrust. The boring bar was run at 1,200 r.p.m. with .002 in. feed. Material machined: phosphor bronze bushes. Tools: tungsten carbide (Jones & Calver C.F.). 2 in. dia. bearing, 5 in. long, 1⅞ in. dia., bearing 3½ in. long. Metal removed .014 in. dia., i.e. .007 in. per side. The two bearings were machined separately, cutting time being 3.5 mins. approximately, and floor to floor time, 8 mins. The ovality of bores was within .0002 in., taper was .0001 in., and there was no apparent out of line between the two bores when a bar was passed through them approximately .0002 in. down in diameter. The previous method of manufacture of these barrels was on an internal grinding machine where each end was ground separately. The time thus taken was approximately 40 mins. per barrel, and the surface finish in the bronze was unsatisfactory and tended to give heat in the running-in stages.

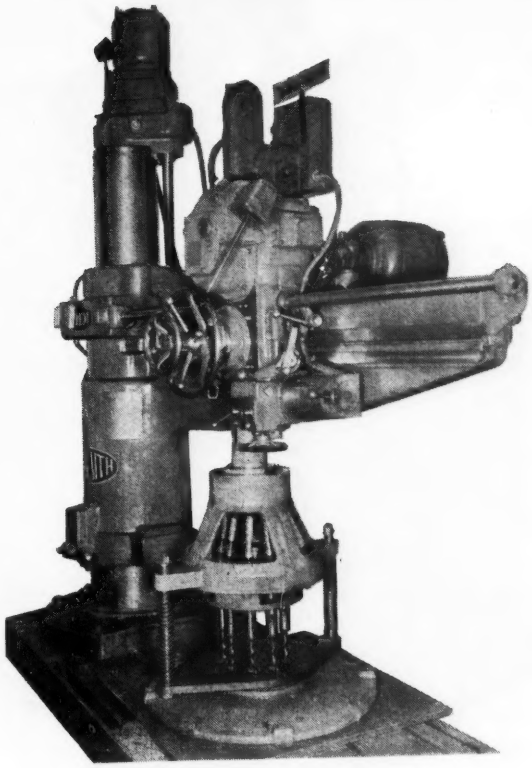


Fig. 3. This illustrates the use of a 6 ft. O.D.1 radial as the medium for driving a nine-spindle multi-head attachment. The installation is at the works of Cockshutt Farm Equipment Ltd., of Brantford, Ontario, and it was entirely the firm's idea to use such a set-up. The multi-head weighs 300 lb. and has nine spindles on a P.C.D. of 14 in. The diameter of holes to be drilled are $\frac{3}{4}$ in. and the component is a cast iron wheel hub for use on farming equipment. The quantities were such that a special machine could not be justified.

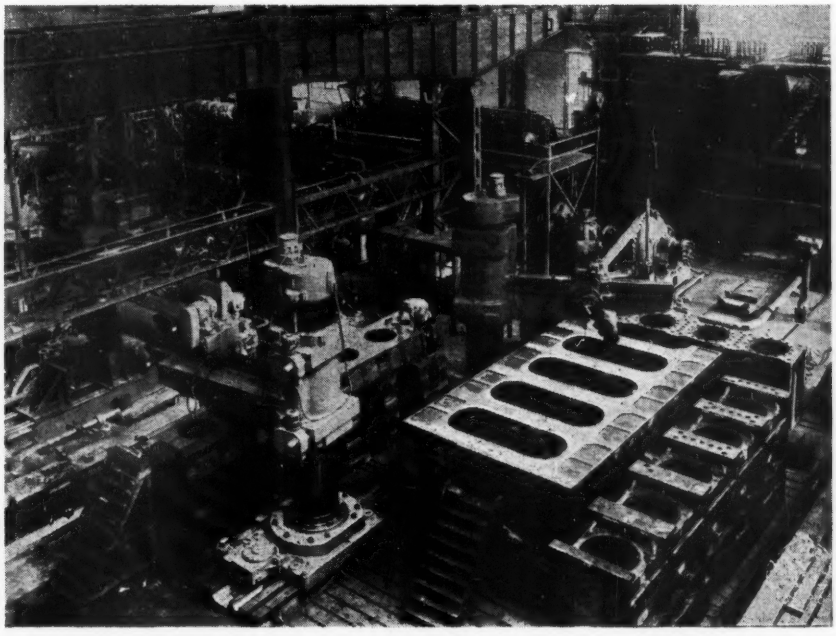


Fig. 4. This is an example of the use of radials on traverse beds and, in this case, shows two machines mounted on one bed, demonstrating how different types of jobs can be machined at the same set-up. Here, two machines cover the same area as two or more much larger radius machines, placed in fixed positions.

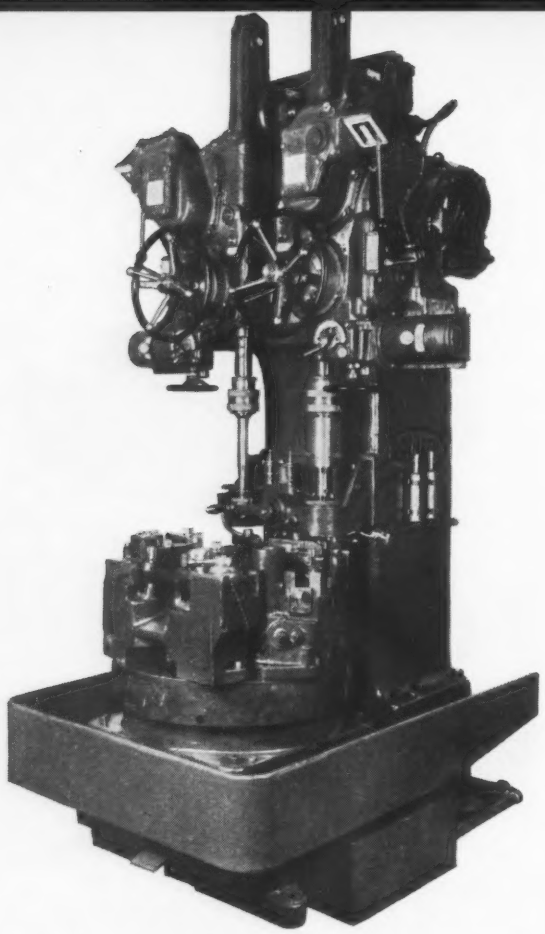


Fig. 5. A standard Asquith U.G.D. vertical drilling machine fitted with special indexing table and fixtures for, first, rough drilling the little end and big end bores on Merlin engine conrods, and then boring out these bores to limits of .001 in. on centres. The bores were then finished on a fine boring machine. This type of set-up is applicable when quantities do not justify the cost of a special purpose machine.

Asquith's were the first to adopt this design, which eliminated a considerable amount of shafting, gearing, etc., and thus gave higher efficiency to the drive.

The natural sequence to this was the design of a machine whereby the motor could be mounted directly on to the saddle. In the United Kingdom the motor was so mounted about the 1920's, and specially designed electrical gear was developed by British electrical motor manufacturers.

At the same time, special higher tensile strength steels became available for gears and shafts, and processes for hardening of gears became available.

The above factors enabled smaller members to be used which, in conjunction with the new type of motor that was available, allowed for a complete assembly drive to be used inside a casing in conjunction with the drill spindle, which was now of a more refined nature and smaller dimensions. Thus a more efficient slide became available, with consequent higher ranges of speeds, and incorporating refinements to the spindle and spindle barrel design.

Simultaneously, refinements were being made to the mounting of the arm on the pillar, to extend its manoeuvrability, and also improvements in locking systems, which resulted in the basis of the design as it is known today.

Multiple setting

This meant also that the radial drilling machine became radial in the fullest sense, in that it could be rotated through fully 360°. Arising from this development, far more use was made of what is now termed multiple setting, i.e. the putting down of four base plates instead of the customary one, so that jobs could be set up whilst others were being drilled.

This, however, could not be claimed as being due to the development in the motor mounted on saddle design; it really commenced when the electric motor was first used as a direct drive mounted on the arm. Even when it was mounted on the floor, only three positions were really available.

With the introduction of the direct drive machines, it soon became apparent that the stage had been reached when the drilling machine could no longer be looked upon as a mere puncher of holes, and that far greater use could be made of it.

My first experience of using a radial drilling machine for boring came in my early days as a Service Engineer, when I was at the Morris Commercial Company at Coventry. An Asquith O.D.1 radial was being used for the boring of Morris engine cylinder blocks; the boring bar being piloted top and bottom. Quite a good job was produced, but this, however, was only a roughing operation.

Use of tungsten carbide

As various types of cutting tools developed, together with investigations into the use of tungsten carbide and improvements in jig and fixture design, it became apparent that the drilling machine, because it was, in the case of a radial, so easy to manipulate and had quite a good selection of speeds and feeds, could be used as a boring machine, provided that a flexible drive was used between the boring bar and the drill spindle.

This was essential, because the radial arm is a cantilever with a bending moment, and due to having to compensate for the thrust of the cutting tool, it is deliberately designed with the arm, as we say, pointing down. Therefore, if a boring bar or any other tool is inserted directly into the Morse Taper of the spindle end, it will be out of square in relation to the workpiece.

It is, therefore, essential to have the tool driven in such a way that it can float and thus prevent any pull or drag taking place between the tool and the pilot bushes in the fixture. If accuracy is to be maintained in the job to be produced, the pilot bushes must be manufactured to close running tolerances, i.e. in the case of revolving bushes, this running tolerance should be between the outer diameter of the bush and the inner diameter of the bore in the fixture, and in the case of a fixed bush and rotating tool, between the outer diameter of the tool and the inner diameter of the bush.

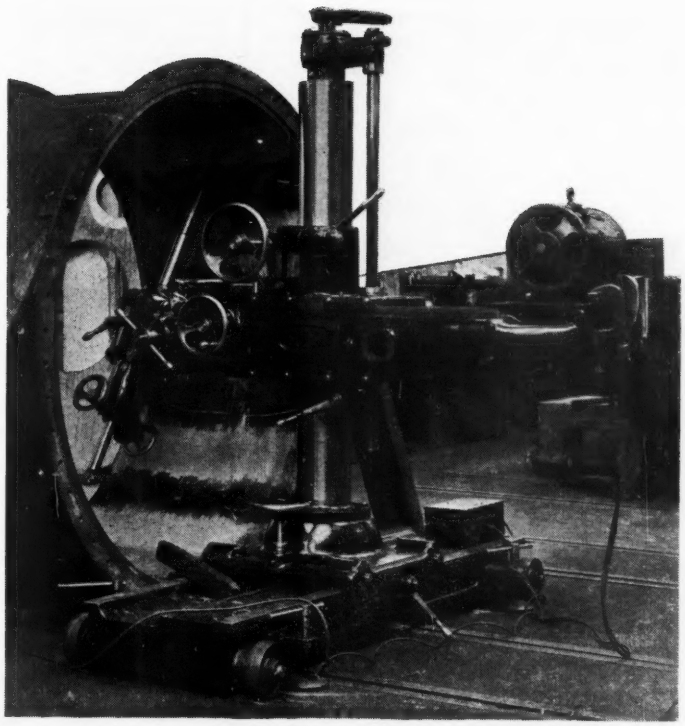


Fig. 6. An example of the use of a portable Universal drilling and tapping machine for the drilling and tapping of holes round the internal faces of a cylinder. This type of machine is of considerable use where holes must be machined on large components and it is more advantageous to take the machine to the job.

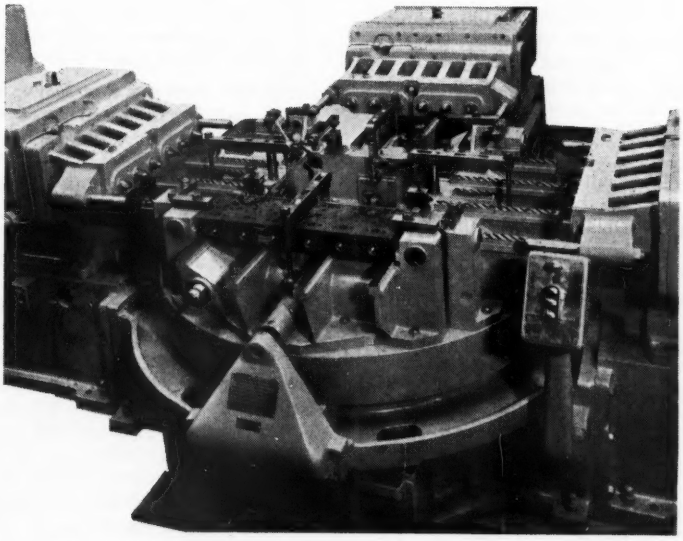


Fig. 7. A three-way multi-spindle machine for machining the cylinder head of a diesel engine. This is a typical example of indexing table set-up with three components being machined at the one setting, another being removed during the machining operations, and another loaded into the fixture. This table is hand-operated.

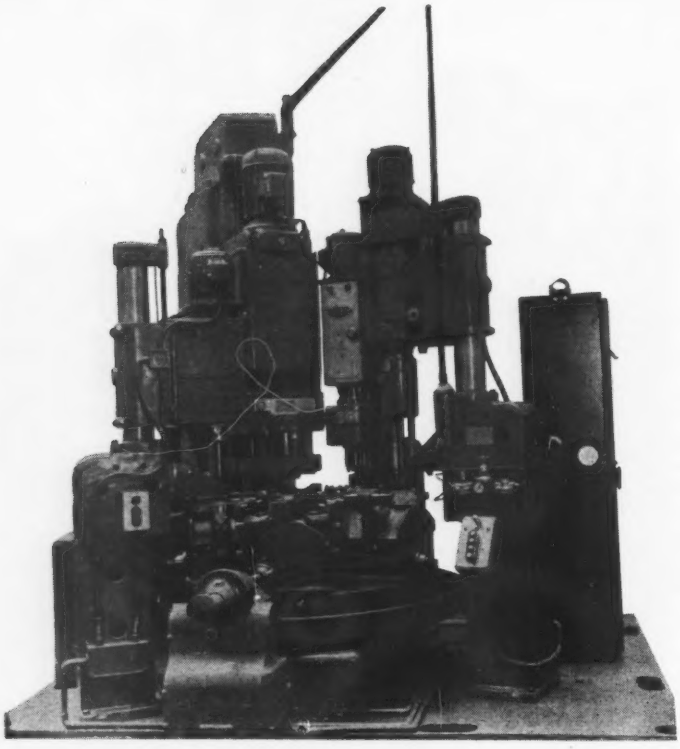


Fig. 8. A rotary transfer type machine for drilling, tapping, reaming and chamfering holes in a mtor car engine induction pipe. There are five stations, each having one duplex fixture, which are arranged to accommodate two components presenting alternatively the top and bottom faces of the centre boss of the component. The components are located from two holes previously drilled and reamed, and are clamped by means of an electrically-operated chuck way. The table is power-indexed, as against the hand-indexing type, and is operated by push buttons on the main control panel. When indexing, the weight of the table and the fixtures is eased from its track during the rotation. The machine works to an automatic cycle of quick approach, feed and quick return to starting position. (Cycle time : 40 secs.)

The bushes must also be designed to eliminate the possibility of seizing-up, due to the presence of swarf, but this is not a difficult matter to overcome.

It should, however, be pointed out that as the machine is being used as a driving medium, the accuracy of the work to be produced will depend on the accuracy to which the fixture and piloting media are produced.

I would emphasise that although various boring operations can be and are being carried out on drilling machines, it is not claimed that this type of machine can replace the horizontal boring machine. Obviously, the size of the job which can be accommodated and the question of facing limits its range. What I do claim is that many operations hitherto considered suitable only for elaborate and expensive machines can, if properly planned and tooled up, be carried out on drilling machines. There is the great advantage that all the drilling and boring operations within the range of the machine can be carried out on the same machine, instead of merely doing the drilling, tapping and reaming on the drilling machine, and then transporting the component or resetting on a boring machine.

It will be appreciated, from the description of the radial drilling machine, that the drill slide assembly is a complete unit and, therefore, could be mounted on different types of structures.

There is the vertical type of machine, consisting of this unit mounted on a column and arranged with a table to give a compound movement, so as to move the workpiece quickly under the spindle centre. This type of structure is more rigid than the radial drilling machine, but it is not as flexible in its operation.

If the workpiece is large, one or more of these units can be mounted on a crossrail, with a table underneath, this table being of either a static or traversing type.

The drilling unit slide can also be modified so that it is suitable for working in a horizontal direction, i.e. the horizontal drilling machine. With such a machine, a rotary table could be mounted in front of the machine, which would enable machining to be carried out on four sides of the component at one setting.

The foregoing types of machines are generally used for general engineering production where batch quantities are relatively small. Figs. 1 - 6 show a few examples of the use of standard type drilling machines. After this stage, the quantity of production of the component determines the character of the type of machine which is required.

Under these conditions, machines carrying a group of spindles arranged in a suitable pattern of holes to suit the component are used, and these are what we term multiple spindle drilling machines, on which operations of drilling, reaming, tapping, boring, counter-boring, recessing and chamfering, etc., can be carried out.

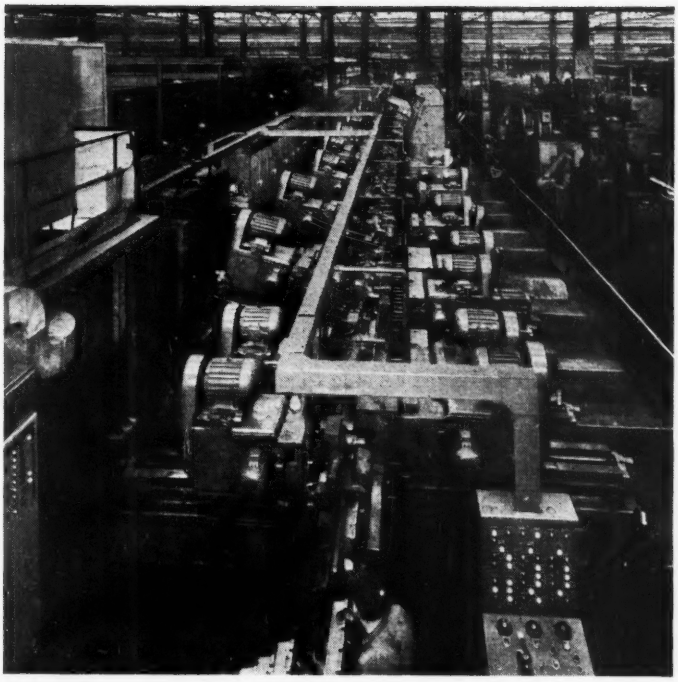


Fig. 9. Layout of a fully automatic in-line transfer machine for machining all holes in cylinder heads. Five different types of heads are catered for — four and six cylinder petrol as well as diesel — having an average of approximately 50 holes. The components are presented to the machine with the required faces machined and location holes reamed to size. The machine comprises 30 machining stations, with 51 machining heads, and its total length is 165 ft. There are three sections to the machine, three transfer bars and two tilting stations, a section being a length of the machine through which the component passes in one plane and for which a common transfer bar is used. As this machine caters for five different components, provision has to be made for selection of the operation of only those heads necessary for the machining of each component. This is done by manipulating a component selection switch on the master panel. The switch is then locked in position. This selection brings into circuit the required machining heads and discards others, which are maintained in returned positions. Other conditions relative to selection are: clamp bar switches are selected, while pressure switches confirm clamping pressure; contact switches are used to indicate that wedge bars have moved to the required clamping position for a selected component, as these differ in thickness. This is to safeguard against jamming actions indicating by pressure only that clamping has taken place before, in fact, clamps have met the component. If the components are not in the fixture during machine loading or emptying, the wedge pad bars will over-travel and depress a further contact switch, which will give signals as if a component was present and correctly clamped. At the front of the machine is the loading station, carrying guide rails into which the component is pushed manually against a length stop, which ensures correct positioning for the engaging of the transfer bar pawls. Also at this station are contact type switches which scan the length of the component for correct loading position and probe for the correct component according to the selection made on the control panel selection switch. The Cycle Start button is then pressed and lights on the panel indicate that all the various functions of the machine are in operation. The transfer bar pawl pulls the component into the first machining station, the locators engage in the reamed locating holes, the component is clamped and the machining heads are started on their cycle. At the completion of the machining operation, the component is unclamped, and dowels retract to the next station. During the cycle of operations, the component is tilted and rotated so as to present the faces to be machined in the correct position, and the component can then be transferred to the next station, this being effected by again pressing the Cycle Start button. The cycle time on this machine is 1 min. 20 secs.

It is generally true to say that this technique can be most economically applied where the holes are more than six in number, providing always that the batch quantities justify it.

Under this condition, the question of loading and unloading of the component during cutting is given special consideration, as this can greatly influence the floor-to-floor time. Therefore, these machines have a completely automatic cycle. They can be grouped together by means of a conveyor system, so that the component can be transferred from one machine to another, but in this case the transfer is made manually.

In order to reduce the number of operators for a batch of machines carrying out all suitable operations on a component, the machining units are linked together and an automatic conveyor system, and automatic location and clamping equipment, are incorporated. The component is transferred from one station to another by power — the whole cycle being completely automatic and controlled from one master control panel.

These machines can be of either the rotary or line type, and are classified as transfer machines. Figs. 7 - 9 show examples of special machines.

In this Paper, I have tried to give you a picture of the natural developments leading up to present-day machines and, I would add, that nowadays we refer to them not as drilling machines but as drilling, boring, reaming and tapping machines, because their applications have so greatly increased.

Production Engineering Research Association of Great Britain

Quarterly Newsletter to the Institution

Associate Membership

Under an agreement which has recently been approved by PERA Council, technical colleges and universities will in future be able to make use of a number of the Association's research, information and educational services. A form of Associate Membership has been created which is open to all technical colleges and universities in Britain and the Commonwealth, and a number have already been elected to membership.

Colleges and universities are being admitted to Associate Membership because it has become essential for students of production engineering to receive instruction in the new and improved techniques continually being developed by PERA. Some students employed in firms which are members of PERA learn about these advances in the course of their daily work, but many students are not aware of the Association's researches into pressworking, machining, machine tools, etc., and on completion of their training will therefore be using techniques which have already been superseded by more effective practices in other firms.

Services Available

Services which are available to Associate Members include the following :-

Research Reports

Copies of reports on PERA investigations can be obtained when they are released to Associate Members by PERA Council. Reports at present available deal with investigations into the design and performance of machine tools, cutting fluids, metal cutting operations, and pressworking techniques.

Bulletins

The monthly bulletin contains a digest of the contents of about 500 technical journals, classified under headings covering the whole field of production engineering.

PERA Library

All the facilities of the Association's Library, which now contains about 100,000 items of literature, are

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NEW YEAR THOUGHTS — concluded from page 2

let us first of all ask ourselves whether at any time in the course of our careers we have not been his unconscious accomplices. It is easy to see the mote in his eye. Let us be very sure there is no beam in our own.

A long list of scientific discoveries and inventions characterises our epoch. Let us not forget, however, that three-quarters of John Citizen's household budget is still laid out on the type of goods and services which were known in the time of Isaac Newton; housing, clothing, food, the education of children, transport and other services. A one per cent. advance in productivity related to these fundamentals would be the equivalent of a three per cent. advance on the balance remaining. So long as too many of our industries are unprepared, for whatever reason it may be, to buy and install the best capital goods in the shop window, and to use the most up-to-date methods in putting them into service, it is useless to look to science and invention as the panacea of our ills.

The New Year is a time for good resolutions. It is also a time for stocktaking. Resolution without stocktaking is a good recipe for platitudinising. That is why so few of the New Year's resolutions get kept. For any shortcomings in production of which we may become aware in 1958, let us therefore be sure that we give ourselves a full measure of blame before blaming others. As a New Year resolution it may sound a grim one, but no grimmer, maybe, than the year to come.

freely available to Associate Members. The collection of literature includes books, periodicals, special reports, reprints, standards, trade literature, etc. To facilitate searches for information, the Association has developed a comprehensive classification scheme which takes into account the special needs of production engineers.

Mobile Demonstration Unit

The Mobile Demonstration Unit, consisting of a lecture theatre and demonstration bay, continuously visits members in all parts of Britain. Lectures and demonstrations are given by senior engineers, and films made by the PERA Film Unit are shown in the theatre. Visits can be arranged to all Associate Members.

Training Courses

Associate Members' staff can attend various courses held at PERA. These include five-day intensive training courses on machining, pressworking, inspection, method study, machine tools, metal forming, automation, etc. ; two-day courses on tool grinding, machine tool maintenance, etc. ; and a six-month course of training in the methods and equipment developed by the Association for the general improvement of production processes and the solution of particular production problems as they arise in factories.

Practical Research

The Association is prepared to undertake research and other practical investigations for Associate Members on payment of the net cost of the work.

Collaboration on Research

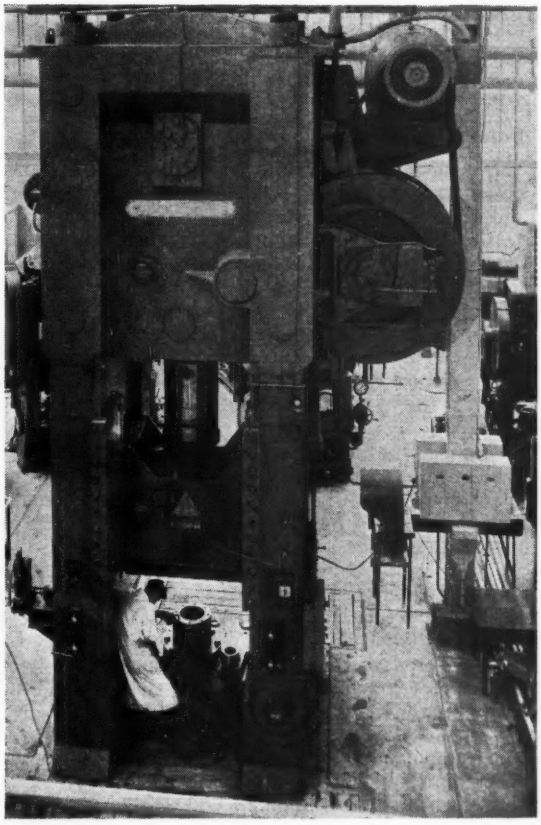
Associate Members will be encouraged to collaborate with PERA on research projects related to industry's needs for reliable information about various aspects of production. Assistance in carrying out such research will if necessary be given by PERA.

The Association would be pleased to receive a visit from a member of staff of any college or university which is interested in Associate Membership, or alternatively, will arrange for a senior engineer to visit the college. In addition, Mr. F. W. Cooper, Educational and Technical Officer to The Institution of Production Engineers, who recently visited PERA to study the ways in which Associate Membership will assist universities and colleges to keep abreast of developments in production techniques, will be glad to discuss the matter with anyone who requires further information.

PERA's Information Manager, Mr. D. D. Morgan, would be pleased to deal with enquiries concerning the Association's work. The address is :

" STAVELEY LODGE,"
MELTON MOWBRAY,
LEICESTERSHIRE.

Telephone: Melton Mowbray 535.



This 1,000-ton press, recently finally installed in PERA workshops, is now being used for research into the extrusion of large components.

MATERIALS HANDLING GROUP

Meeting of Region and Section Representatives

THE first meeting of the Region and Section Representatives and the Group Committee took place at the Regent Hotel, Leamington Spa, on Monday, 28th October, 1957, under the Chairmanship of Mr. A. G. Hayek, the Chairman of the Materials Handling Group Committee.

The meeting was honoured by the presence of Mr. G. R. Pryor, a Vice-President of the Institution, and Chairman of the East and West Ridings Region; and Mr. R. W. Hancock, Chairman of the South Western Region.

The Chairman gave a brief résumé of events leading to the establishment of the Group and the activities which had been undertaken by the original Sub-Committee. Some of these were:

(a) the preparation, in conjunction with the Education Committee, of a syllabus on Factory Layout and Materials Handling which is now being integrated into the new examination structure of the Institution as a Part II subject;
(b) the publication of case studies;
(c) the exhibition of films;
(d) the presentation of lectures;
(e) the organisation of an annual convention.

It was the aim of the Group to be a source of knowledge on all aspects of materials handling for the benefit of the membership of the Institution, and British industry as a whole.

Future activities

During the meeting, plans were laid for the future activities of the Group, which will function through the existing Region and Section structure of the Institution. Small units in the Sections will act as working parties for the collection and propagation of information. Some aspects of the subject will be reported upon by all Section units participating, and other aspects will be the responsibility of individual units, but all information will be channelled through the central Committee which will act as a "post office" for disseminating the material received. Eventually, it is hoped to have available information on lectures, films, courses of instruction; abstracts of articles in current periodicals; reviews of books; and the Group will continue to organise an annual Convention and to provide Case Studies for inclusion in the Journal.

The Section Representatives expressed their enthusiasm about the future programme and promised their wholehearted support in an effort to achieve the aims of the Group.

It was arranged that the next meeting of the Region and Section Representatives with the Group Committee should be held about April next.

Institution members interested in the Group should make application to the Materials Handling Group Representative in their Section; a list of these is shown in the next column.

REGION REPRESENTATIVE

MIDLAND — R. Wheeler, A.M.I.Prod.E., Old House Farm, Parish Hill, Bournheath, near Bromsgrove, Worcestershire.

SECTION REPRESENTATIVES

BIRMINGHAM — B. H. Horton, A.M.I.Prod.E., 40 Broad Road, Acocks Green, Birmingham, 27.

BIRMINGHAM GRADUATE—R. C. Short, Grad.I.Prod.E., 41 Witherford Croft, Blossomfield, Solihull, Warwickshire.

COVENTRY — A. C. Evans, Grad.I.Prod.E., 135 Kenpas Highway, Coventry.

EDINBURGH — F. H. Eccersley, M.I.Prod.E., 3 Queen Margaret Drive, Auchmurty, Glenrothes, Fifeshire.

LEEDS — J. M. Wilson, M.I.Prod.E., W. & T. Avery Ltd., Sherburn-in-Elmet, near Leeds, Yorkshire.

LEICESTER — R. D. Owen, A.M.I.Prod.E., 24 Hylion Road, Knighton, Leicestershire.

LIVERPOOL — F. H. Booth, A.M.I.Prod.E., Vernons Industries Limited, Kirkby Industrial Estate, Liverpool.

LONDON — C. Cooper, M.I.Prod.E., 126 The Ridgeway, Enfield, Middlesex.

LUTON — M. R. Barton, A.M.I.Prod.E., 20 Burymead, Stevenage, Hertfordshire.

MANCHESTER — H. C. Knott, M.I.Prod.E., The Knowles, Horwich, Bolton, Lancashire.

PETERBOROUGH — W. Peck, M.I.Prod.E., 7 Norfolk Street, Peterborough.

PRESTON — H. S. Carleton, A.M.I.Prod.E., Rose Cottage, Dark Lane, Ormskirk, Lancashire.

READING — H. P. Mott, A.M.I.Prod.E., Apple Trees, Burfield Common, near Reading, Berkshire.

SHEFFIELD — H. Steel, A.M.I.Prod.E., The Brightside Foundry & Engineering Co. Ltd., G.P.O. Box 118, Sheffield, 1.

SHREWSBURY — W. Castledine, M.I.Prod.E., Croft, Bargates, Whitchurch, Shropshire.

SOUTH ESSEX — H. C. Perry, M.I.Prod.E., 76 Highlands Gardens, The Drive, Ilford, Essex.

STOKE-ON-TRENT — A. G. Hayek, M.I.Prod.E., A. G. Hayek & Partners Ltd., Federation House, Stoke-on-Trent, Staffordshire.

SWANSEA — G. E. Halter, M.I.Prod.E., Leigh Beck, Charles Street, Skewen, Glamorgan.

TEES-SIDE — T. H. Hall, M.I.Prod.E., Head Wrightson (Teesdale) Ltd., G.P.O. Box 10, Teesdale Iron Works, Thornaby-on-Tees, Yorkshire.

WESTERN — G. A. Daniell, A.M.I.Prod.E., Chief Work Study Engineer, Bristol Aircraft Ltd., Filton, Bristol.

WOLVERHAMPTON — J. R. Allan, A.M.I.Prod.E., Acme Conveyors Ltd., 1 Bradford Street, Walsall, Staffordshire.

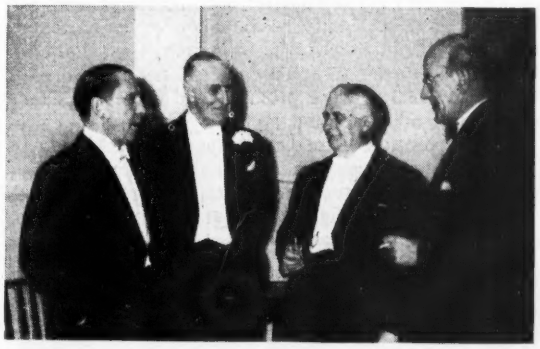
INTERESTING EVENT FOR MIDLAND MEMBERS

The effects on the production process of the outlook of the individuals who go to make up a factory unit are among the most vital factors which a production engineer must take into account. The viewpoints of management and labour may be in harmony, or they may be opposed, but no matter how good the management concerned, unless these viewpoints are sympathetically understood the full benefit of new materials and processes will never be realised.

Members in the Midlands will have an unique opportunity of gaining an insight into these points of view when Sir Ewart Smith, Vice-Chairman of I.C.I. Ltd., and Sir Tom Williamson, Chairman of the T.U.C., meet on the same platform at the College of Technology, Gosta Green, Birmingham, on 19th February, 1958, at 7 p.m. They will invite questions on "Trade Union and Management Viewpoints on Modern Production Developments", and although they are old friends, and have appeared on the same platform before, neither has yet converted the other to his way of thinking.

Each has had very considerable experience in the industrial field, and Midland members of the Institution are fortunate in being able to question these two leaders at a meeting of this kind. Tickets for the meeting may be obtained on application to the Hon. Secretary of the Birmingham Section, Mr. H. W. White, "Spring Pools", 677 Birmingham Road, Lydiate Ash, Bromsgrove, Worcestershire.

DINNER AND DANCE AT HALIFAX



This photograph, taken at the successful Dinner and Dance held by the Halifax and Huddersfield Section on 25th October last, shows (left to right) Mr. Robert W. Asquith, who proposed the toast to the Institution; Mr. W. A. Hannaby, Chairman of the Section; Mr. G. Ronald Pryor, Chairman of the East and West Ridings Region, and Institution Vice-President; and Mr. J. E. Hill, Vice-President of the Institution

WESTERN SECTION DINNER AND DANCE

The Annual Dinner and Dance held by the Western Section on 24th October last was again a most enjoyable occasion. Among the principal guests were the Chairman of Council, Mr. H. G. Gregory, and the Secretary of the Institution, Mr. W. F. S. Woodford, and Mrs. Woodford

MATERIALS HANDLING CONVENTION, 1957

OVER 120 members, and others with special interests in Materials Handling, attended the three-day Convention held at Leamington Spa from 28th - 30th October last, which was organised by the Materials Handling Group Committee of the Institution. All areas of the country were represented and some delegates came from as far afield as Scotland and Cornwall. The delegates were kept busy from arrival to departure, but such was the enthusiasm displayed that the evening meetings of the various Syndicates were prolonged in some cases far beyond the allotted time.

The Convention opened on the evening of Monday, 28th October, with an informal dinner in the Assembly Room of the Leamington Town Hall.

After dinner, the eight Syndicates met for briefing by their respective chairmen.

The Mayor of Leamington, Councillor Eric Lucas, J.P. (left), receives the principal speaker, Major-General K. C. Appleyard, C.B.E., Past President of the Institution. In the centre is Mr. A. G. Hayek, Chairman of the Materials Handling Group

The morning of Tuesday, 29th October, was occupied with factory visits, the first party leaving the Town Hall at 8.45 a.m. The local companies who had previously been approached by the Group Committee to act as host firms, co-operated enthusiastically in these visits, and the Institution is greatly indebted to the following, in this connection: The Associated Portland Cement Manufacturers Ltd.; The Imperial Foundry Company; Joseph Lucas Ltd; The Lockheed Hydraulic Brake Co. Ltd; The Standard Motor Company Ltd.; and to Mr. R. G. Cox, F.R.I.B.A., of Clifford, Tee and Gale.

Syndicate discussions

The subjects chosen for these visits and for subsequent discussion by Syndicates during the Convention covered many specialist aspects of materials handling, and included handling of bar in long lengths; handling of swarf; handling of small components; the introduction of mechanical handling methods into a small factory (i.e. employing fewer than 50); the mechanised foundry; handling of loose bulk material; handling problems created by the introduction of transfer mechanisms; and a case study on the collaboration between the Architect and the Production Engineer in designing a new building.

All visits were completed on the Tuesday morning, and the afternoon was spent by each of the Syndicates in discussing what they had seen, and in preparing their reports.

On Tuesday evening the Mayor of Leamington, Councillor Eric Lucas, J.P., held a Civic Reception in the Town Hall for Convention members, and this was followed by the Convention Dinner, at which the principal guest was Major-General K. C. Appleyard, C.B.E., T.D., D.L., Past President of the Institution.

A stimulating address

In a stimulating address, General Appleyard said that the country appeared to be faced with quite a long period of economic stress. In his opinion this might well be good for us. It would put the nation under pressure to make the best use of her brains and resources, to enable her to meet the growing competition from other nations, particularly Germany and Japan. Given good industrial and political leadership, and the opportunities for the country's technical and scientific brains to use their imagination, we did not have too much to worry about.

Unfortunately, continued General Appleyard, the country's capital wealth had been lost, and there was

Mr. L. J. Hoefkens, Central Materials Handling Engineer, Lockheed Hydraulic Brake Company, and a member of the Group Committee, is seen here dealing with questions during the tour of his Company's works by members of Syndicate B (Handling of Swarf)

an insufficient margin to meet any considerable period of adverse trade or, indeed, to meet the demands of first-class trading conditions. More production was necessary, but this could generally be achieved where the management and the leadership were good. Looking to the future, he was no pessimist in this respect, because a lot of fine young men were coming on who were steadily taking over and doing a first-class job.

General Appleyard felt that the genius that had enabled this country to lead the world in so many ways could be applied with great success to overcome present problems, particularly in the vital elimination of waste — waste in time, manpower, materials and money. This was, he stressed, the basis of the work of The Institution of Production Engineers — the elimination of waste.

Finally, said General Appleyard, he looked forward to the growth of the Materials Handling Group, to the expansion of its interests and enthusiasm, resulting in a long series of useful contributions. He felt sure this work would help all in British industry in an era of severe competition.

The morning of Wednesday, 30th October, was devoted to the presentation of the Syndicate reports, and after luncheon the Convention heard a thought-provoking Paper on "The Mathematics of Handling", presented by Dr. K. D. Tocher, Research Applications Manager, The United Steel Companies Ltd. The Paper was followed by general discussion, and the Convention ended at 4.30 p.m.

The Group Committee are particularly grateful to the Mayor and Corporation of the Borough of Royal Leamington Spa, and to the Spa Manager, Mr. J. W. Nunn, for the excellent arrangements made for the housing of the Convention and the generous facilities offered to delegates.

Enquiries are already being received regarding the next Group Convention, and the Group Committee are actively engaged in drawing up a programme. They would welcome any suggestions from members for subjects for discussion at the next Convention.

(NOTE—The Convention at Leamington was preceded by a meeting of the Materials Handling Group Committee with Region and Section representatives, to discuss future policy. This meeting is reported on page 52 of this Journal.)

DIARY FOR 1958

2nd and 3rd January	**Sixth Annual Aircraft Production Conference, Southampton.**
6th February ...	**The 1957 Viscount Nuffield Paper,** to be presented at the University of Bristol. Speaker: **Lord Hives.** Subject: **"Technical Education for Production Engineers".**
24th March	**The 1957 George Bray Memorial Lecture,** to be presented at the University of Leeds. Speaker: **Dr. V. E. Yarsley.** Subject: **"The Fabrication of Plastics".**
9th and 10th April ...	Conference on **"Compressed Air in Industry"**, Camborne, Cornwall.
12th - 21st May ...	**Production Conference and Exhibition,** Olympia — **"Production Fights Inflation".**
21st May	**Fourth Conference of Engineers** and those responsible for Standards matters in Industry, London.
27th - 31st August ...	**Annual Summer School,** Ashorne Hill, Warwickshire.
29th October	**Annual Dinner of the Institution,** Dorchester Hotel, London.

news of members

Mr. A. Ainsworth, Associate Member, has recently relinquished his position with Teddington Aircraft Controls Limited, Merthyr Tydfil, and has set up his own business in the Manchester area.

Mr. R. J. Bailey, Associate Member, has been appointed Liaison Design and Production Engineer for Martonair Limited, Farnham Trading Estate.

Mr. S. K. Banerjee, Associate Member, has recently relinquished his position as Chief Jig and Tool Designer with Textile Machinery Corporation, Belgharia, to take up an appointment as Chief Planning Engineer with Britannia Engineering Co. Ltd., Titaghur, West Bengal, India.

Mr. C. E. Cumins, Associate Member, is now a Senior Lecturer in the Mechanical / Production Department at Hatfield Technical College.

Mr. W. Frakes, Associate Member, has now joined the United Kingdom Atomic Energy Authority, as a Group Engineer at the Windscale Works, Cumberland.

Mr. B. Fraser, Associate Member has now relinquished his position as Senior Tool Development Engineer with Short Brothers & Harland, Belfast, and has taken up a position as Investigation Engineer with The English Electric Co. Ltd., Guided Weapons Division, Stevenage.

Mr. C. T. Gould, Associate Member, has been appointed Chief Work Study Engineer of The Reed Paper Group. His appointment is part of the development of advisory services within the Group. Initially Mr. Gould will be attached to the Mills Division, but his services will also be available to converting companies. He was formerly Head of Production Study in Unilever Limited.

Mr. J. S. Hopkinson, Associate Member, has been appointed Works Manager of the Anglo-Celtic Watch Co. Ltd., Ystradynlais, South Wales. Mr. Hopkinson, who for the past seven years has served on the Committee of the Swansea Section of the Institution, is also a corresponding member of the Papers Committee and represents the Institution on Swansea and District Local Productivity Committee.

Mr. S. S. Jauhari, Associate Member, has been appointed to the following Committees of the Government of India: Technical Committee to examine the project for setting up a plant for the manufacture of coal mining machinery; Machine Tools Loan Advisory Committee; and a Sub-Committee of the standing Metric Committee.

Mr. G. S. Mutch, Associate Member, has recently taken up an appointment with the Scottish Education Department as H.M. Inspector of Schools.

Mr. E. C. Nicholson, Associate Member, has been transferred from the Rugby Works of The English Electric Co. Ltd., to the Preston Works as a Production Engineer (Aircraft Division).

Mr. G. L. Rogers, Associate Member, has accepted a position as Plant Engineer with African Explosives and Chemical Industries Limited, Transvaal, South Africa.

Mr. L. H. Sanders, Associate Member, has relinquished his position as Senior Production Engineer with Ultra Electric Limited, in order to take up the appointment of Project Manager with Visual Planning Systems Limited, of Alperton.

Mr. A. R. Buckley, Graduate, has relinquished his appointment with the British Ceramic Research Association, and has taken up a position as Assistant Lecturer in the Engineering Department of the South Staffordshire Technical College.

Mr. K. J. Buckton, Graduate, has relinquished his position as a Methods Engineer with Messrs. Carreras Limited, and has taken up a new position with Messrs. Reeves & Co. (Birmingham) Limited, as General Manager.

Mr. M. Dewhurst, Graduate, has now completed his training with David Brown Industries Limited, and has taken up a position as Sales Engineer with David Brown Corporation (Sales) Limited, Newcastle-upon-Tyne.

Mr. K. Ghatak, Graduate, has now left the Washington University, St. Louis, and has taken up an appointment in the Steam Turbine Department of the Allis Chalmers Manufacturing Company, Milwaukee, Wisconsin, U.S.A.

Mr. R. G. F. Lowe, Graduate, is now Assistant to the Managing Director at Messrs. W. W. Greener Limited and B. H. Pottier & Co., Birmingham. Mr. Lowe is Lecture Secretary of the Birmingham Graduate Section Committee.

Mr. R. Moon, Graduate, has recently been appointed Development Engineer at the Watford factory of S. Smith & Sons (England) Limited.

Mr. E. Walker, Graduate, has taken up an appointment as Production Engineer with the Southern Railway of Peru, South America.

Mr. E. Williams, Graduate, has relinquished his position with The Plessey Co. Ltd., of Ilford, Essex, and has taken up the appointment of Assistant Works Manager with P. C. Henderson Limited, Romford, Essex.

ASSOCIATE MEMBERSHIP EXAMINATION, 1957

PASS LIST — PART I

Clifford A. Bailey
Dennis N. Bird
John G. Burrow
James R. Campbell
Roy K. Charlton
A. C. Clegg
Alan R. Dove
William J. Dunn
Colin B. Dymock
F. E. Ellen
Arthur G. Griffiths
Alan Hackett
Abdul Haleem
Charles F. Holding
Terence P. James
D. Jenkins
John H. Kane
Robert W. Periam
Francis J. Picken
Clifford Price
T. R. J. Reast
Clifford E. Roberts
Albert D. Rothwell
Anthony Rowland
Gerhard T. Schwartz
Alan Slater
Geoffrey D. Slegg
Reginald J. Spencer
Ridley Stokoe
Bernard Stuart
Peter H. Sturgess
John Walker
Peter M. F. Watson
Edward V. Williams
Robert Williams

PASS LIST — PART II

K. I. Archer
Brian E. Bayley
Michael D. Blake
William C. D. Blower
Harold D. Chapman
Alan R. Creasey
Idris J. Davies
Keith B. Davis
Raymond Dixon
Garth S. Dodd
Alan R. Dove
Kenneth J. Eagle
John E. Ede
Eric K. Ford
Robert W. Gambling
Gwyn Gronow
Ronald Harvey
William H. Hollis
Ronald E. Holman
Terence P. James
James R. Leitch
Thomas McSorley
Stanley V. Page
Raymond O. Parry
Francis J. Ficken
Anthony W. J. Pullen
Henry W. Reece
Donald B. Richardson
Albert D. Rothwell
Alfred G. Saunders
Derek Sawyer
Alan Slater
Bernard Stuart
Frank R. Taylor
B. E. Trott
Norman E. Tyler
Alfred S. Waters
James B. Watson
Maurice R. Wilson
Frank Woodgate

PASS LIST — PART III

John M. Ackland
Clifford Allen
J. A. S. Annatt
James A. Austen
Arthur D. Bailey
Arthur W. Balls
Robert Bell
Michael J. Berry
Dennis E. Bolwell
David Brownlie
Richard P. Burgess
David A. Bowman
Donald S. Busby
Hugh Calderbank
James R. Campbell
Thomas C. Carter
Dennis R. Coburn
Percy N. Coe
Patrick D. Collins
James Connell
Derek J. Dalloway
Eric J. R. Davies
Peter N. Day
John E. Delo
Leon De Boo
James Dickson
Henry Fletcher
Francis R. Funnell
Norman G. Hall
John S. Harman
G. V. Harry
Robert Hastings
Michael J. Hemmett
Barrie O. Hinitt
William H. Hollis
Brian E. Holmes
Evan D. Jenkins
William R. Jones
Vinayak M. Kulkarni
John Leather
W. F. Maidment
Herbert J. Manners
Albert E. Maw
G. C. May
William V. McGrory
Antony B. Merriam
Keith Mitchell
David A. Morrison
Michael M. Murray
Umesh A. Naik
Hector M. Nixon
Richard Owen
Robert W. Periam
Donald G. Petch
Dudley M. Pickard
Jeffrey W. Ramsden
T. R. J. Reast
Henry W. Reece
Maurice E. Reed
Donald B. Richardson
David A. Roberts
Roy E. J. Roberts
Graham Rogers
Anthony Rowland
Alfred G. Saunders
Alan Slater
Andrew Smith
Kenneth Staple
John W. Stevens
Arthur R. Stoddart
Arthur V. Sullivan
William H. Sutton
Charles E. Taylor
Ralph E. Thompson
Bryan E. Thornby
Adrian W. Thorpe
George C. Tomlinson
B. E. Trott
Patrick G. Varley
H. M. S. Von Der Heyde
James B. Watson
Allan Wilkinson
L. A. Kettle-Williams
Edward V. Williams
Frank Woodgate
William York

PASS LIST — PART I (Overseas Candidates)

John S. Baker
John C. Ballard
Gordon D. Gray
Dwadasanta S. Iyer
Prabhakar N. Katdare
Harbans Lall
Prithviraj S. Mathur
Nazir Mohammad
Ambalal D. Patel
Venibhai V. Patel
Graham G. Smith
Gert P. C. Snyman
Syed A. Warsi

PASS LIST — PART II (Overseas Candidates)

Ronald S. Evans
Subramanyachar Nagarachar
Graham G. Smith
Gert P. C. Snyman

PASS LIST — PART III (Overseas Candidates)

Dev P. Batrfa
Boyd Einsiedel
Ronald S. Evans
Konstantins V. Grivainis
Amar N. Haldar
Philip H. Hall
Boris I. Kramer
William Luney
Premsarup Mathur
Robert J. Rainey
Joseph R. Rebello
Max J. Silver
Graham G. Smith
Gert P. C. Snyman
M. A. Wahid

Hazleton Memorial Library

ADDITIONS

Blackburn, R. G. and Cassidy, J. **"Sheet Metal Work. Part 1 — Geometry and Pattern Development."** For the Intermediate Examination of the City and Guilds of London Institute (C.L.G.I.). *London, Edward Arnold,* 1957. 100 *pages. Diagrams.*
Includes examples from past City and Guilds examination papers both as worked examples and as exercises.

Burnham, T. H. and Bramley, D. H. **"Factory Organisation and Management."** (Engineering Economics, Book II.) 7th edition. *London, Pitman,* 1957. 394 *pages. Diagrams.* 25s.
The first edition of "Engineering Economics" was published in 1929, primarily in order to help students working for The Institution of Mechanical Engineers examination in engineering economics which had been instituted in 1924. Its author — T. H. Burnham — was one of the pioneers of management education in this country. He died in 1952, and so, this seventh edition of his book has been revised by other authors: Book I, "Elements of Industrial Organisation", by G. O. Hoskins, and Book II by D. H. Bramley. Book I deals with the economic bases and techniques of industrial organisation. Book II is of more interest to the production engineer since it treats specifically the theory and practice of scientific management, and describes some management techniques. A brief history of scientific management is followed by a study of its basic principles (policy forming; control; delegation; line and functional relationships). The following chapters deal with the personnel function, the design function, the sales function, production facilities (e.g. factory layout); planning and control of production; purchasing; wages and incentives; control of expenditure; estimating. Each chapter could serve as an introduction to the subject treated, and as such should be mose useful to students; first principles are clearly stated and historical precedents are not ignored. There are numerous charts, diagrams, and formulae. The irritating fault of not giving publication dates mars the otherwise useful reading lists added to each chapter.

Gregory, Edwin and Simons, Eric N. **"The Structure of Steel":** a simple explanation for students, engineers and buyers of steel. 3rd edition. *London, Odhams Press,* 1957. 176 *pages. Illustrated. Diagrams.* 18s.
This is as far as possible a "non-technical" explanation of the metallurgical structure of steel and steel alloys. It includes chapters on testing, heat treatment, corrosion and structural effects of mechanical working. There is a glossary.

Higgins, Raymond A. **"Engineering Metallurgy. Part I — Applied Physical Metallurgy."** *London, English Universities Press,* 1957. 404 *pages. Illustrated. Diagrams.* (Technical College Series.) 25s.
This book is intended primarily for students who are taking metallurgy as a subject for the Higher National Certificate in Mechanical or Production Engineering. It covers much of the work leading to the graduateship examination of various engineering institutions. It includes an introduction to such subjects as the crystal structure of metals, their behaviour during thermal and mechanical treatment; the formation of alloys; the surface hardening of steel; to the structure and properties of various ferrous and non-ferrous alloys; machinability; and the metallurgical principles of the joining of metals. A second volume will deal in more detail with the practical aspects of metallurgical and metal working processes.

Liverpool University — Department of Social Science. **"Technical Change and Industrial Relations: a Study of the Relations Between Technical Change and the Social Structure of a Large Steelworks."** W. H. Scott, J. A. Banks, A. H. Halsey and T. Lupton. *Liverpool Liverpool University Press,* 1956. 336 *pages.* 17s. 6d.

Department of Scientific and Industrial Research. **"Men, Steel and Technical Change."** By the Industrial Research Section, Department of Social Science, University of Liverpool. *London, H.M.S.O.,* 1957. 36 *pages. Illustrated. Diagram.* (Problems of Progress in Industry, No. 1.) 2s.
"There can be little doubt that the smooth introduction and assimilation of technical change in industry is of considerable public importance at the present time, and that it may become even more important in the future." So say the authors of the Liverpool University study (of which the D.S.I.R. pamphlet is a summary). In making this study of the relations between technical change, social structure and attitudes to change, the members of the University's Research Team had to decide between making an intensive study of one firm, and an extensive, but necessarily more superficial, study of several. In order to make the study the team considered it necessary to investigate the more important aspects of the social system of the plant and its associated trade unions; and in view of the complexity of the social data, decided to make the study intensive rather than extensive. Eventually the study was limited to one firm which employs over 7,000 persons, and which has a long history of technical change. Moreover, it had recently undergone two major changes, which had been accomplished fairly smoothly. In the report there are chapters on management, on trade unions, and on management-union relationship; and on the attitudes of the employees. It includes an intensive study of the most recent change in the melting shop. In their conclusion the authors say that "the present study has clarified the general factors which have facilitated and impeded change in the steelworks and has thrown some light on the more specific influences which have shaped attitudes to particular changes . . .". They emphasise, however, that their data was insufficiently detailed and reliable to enable them to draw precise conclusions about the relationship between attitudes to change, the impact of change on the systems of rewards, and on the reactions of employees to the changes they had experienced. Their department is, however, conducting further research, and similar studies are being made in other European countries under the auspices of the International Committee for Social Research in Industry. It should, therefore, be possible, in the future, to arrive at more exact conclusions and to make more accurate assessments of the importance of specific cultural and traditional factors.

Hobson, Paul D. **"Industrial Lubrication Practice."** *New York, Industrial Press; Brighton, Machinery Publishing Co.,* 1955. *Various pagination. Illustrated. Diagrams.* 75s.
Deals with the principles of lubrication, types of lubricants and their uses; their physical and chemical characteristics; plain and anti-friction bearings, the organisation of a lubrication department; and the lubrication of electrical machines, internal combustion engines, steam engines, turbines, compressors, refrigeration plant, pneumatic tools, metal cutting and forming machines, gears, chains, ropes and belts.

NOTICE OF EXTRAORDINARY GENERAL MEETING

NOTICE is hereby given that an Extraordinary General Meeting of the Institution will be held at 10 Chesterfield Street, London, W.1, on Thursday, 30th January, 1958, at 2 p.m.

AGENDA

1. Notice convening Meeting.
2. To adopt a Special Resolution that Article of Association 15 should be amended* as follows, viz :- In paragraph (c) the word 'may' where it appears for the second time should be deleted and the word 'shall' be substituted therefore. This part of Article 15 as amended will then read as follows :-

   (c) Have passed the Associate Membership Examination prescribed by the Council's examination regulations for the time being, or such other exempting examinations as may from time to time be approved by Council ; provided that candidates over the age of 35 who have not passed one of the above-mentioned examinations shall be required to pass only such part or parts of the Associate Membership Examination or to submit such Theses as the Council shall direct.

By Order of the Council.

W. F. S. WOODFORD, *Secretary.*

* The word 'may' in the original Article, has been challenged as being ambiguous. The Institution's Council feels, therefore, that this ambiguity should be removed.

NOTICE OF ANNUAL GENERAL MEETING

NOTICE is hereby given that the Annual General Meeting of the Institution will be held at 10 Chesterfield Street, London, W.1, on Thursday, 30th January, 1958 at 2.05 p.m.

AGENDA

1. Notice convening Meeting.
2. Minutes of the Annual General Meeting held on 31st January, 1957.
3. Report on Election of Members to Council 1.
4. Annual Report of Council 2.
5. Presentation of Statement on Income and Expenditure, Balance Sheet and Auditors' Report 3.
6. Election of Auditors, 1957 - 1958.
7. Election of Solicitors, 1957 - 1958.
8. Votes of thanks.

By Order of the Council.

W. F. S. WOODFORD, *Secretary.*

1. See page 61. 2. See page 62. 3. See page 69.

MINUTES OF THE ANNUAL GENERAL MEETING

Held on Thursday, 31st January, 1957.

THE thirty-fifth Annual General Meeting of the Institution was held on Thursday, 31st January, 1957, at 2p.m., at the Headquarters of the Institution, 10 Chesterfield Street, London, W.1. The President, Mr. E. W. Hancock, M.B.E., was in the Chair.

Notice convening Meeting

The Secretary (Mr. W. F. S. Woodford) read the notice convening the meeting.

Minutes

The Minutes of the previous Annual General Meeting, held on 26th January, 1956, were taken as read and confirmed on the motion of Mr. J. H. Winskill, seconded by Mr. E. Percy Edwards, and were signed as correct.

Election of Members to Council

The Report on the Election of Members to Council was received on the motion of Mr. A. Betts Brown, seconded by Mr. R. Hutcheson.

Annual Report of Council

Mr. H. G .Gregory (Chairman of Council) moved that the Annual Report be taken as read and adopted.

Mr. F. T. Nurrish, M.B.E., seconded the motion.

The President invited questions or comment and, none being forthcoming, put the motion for the adoption of the Report, which was carried unanimously.

Statement of Income and Expenditure, Balance Sheet and Auditors' Report

Mr. H. G. Gregory (Chairman of Council) moved the adoption of the accounts. Mr. H. Burke seconded the motion which, there being no questions, was put by the President and carried unanimously.

Election of Auditors, 1956 - 1957

On the motion of Mr. J. H. Winskill, seconded by Mr. A. S. Johnstone, Messrs. Gibson, Appleby & Co., Chartered Accountants, were re-elected Auditors to the Institution for the year 1956 - 1957 and thanked for their previous services.

Election of Solicitors, 1956 - 1957

On the motion of Mr. J. M. Brice, seconded by Mr. G. R. Blakely, Messrs. Syrett & Sons were elected Institution Solicitors for the year 1956 - 1957 and thanked for their previous services.

Votes of Thanks

The President said it was the privilege of the reigning President to propose a vote of thanks to the immediate Past President, to the immediate Past Chairman of Council and to the immediate Past Vice-Chairman of Council, and to all the officers of the Institution. He always liked to thank publicly those who had given their services freely in the endeavour to forward an activity of real worth, and the present was a typical occasion for doing so.

He wished to pay tribute to his predecessor as President, Sir Leonard Lord, a friend whom he had known almost ever since they had been young production engineers together, as they would be called now ; they had called themselves jig and tool draughtsmen. Although members might not have seen a great deal of Sir Leonard in person, he had done, and no doubt would continue to do, a considerable amount of work in the interests of the Institution.

Next there was the man who had really run the Institution, the Past Chairman of Council, Mr. G. R. Pryor, who typified the attributes to which the President had just referred. Mr. Pryor was a completely unselfish man ; wherever in the country he was required, he was there. He had a kindly approach and an ability to make one feel that he agreed with one, although in fact he was violently opposed, which was an art which the President would love to have acquired and a valuable attribute of any Chairman who wished to create a democratic atmosphere. The President knew that he expressed the feeling of every member of the Institution in thanking Mr. Pryor for his excellent service and for the charming way in which he had given it.

One good man begot another, and there was another man to whom the Institution was most grateful, who had been Vice-Chairman of Council and was now Chairman, Mr. H. G. Gregory. Mr. Gregory had acquired the ability to create a free and democratic atmosphere in which to discuss the problems which arose. If there were not differences of opinion in the Council, its members might as well do what was done in some Councils and vote by proxy ; but in fact there was full freedom of speech, thanks to the wonderful pattern set by Mr. Pryor and Mr. Gregory.

The President wished also to pay tribute to the permanent officers of the Institution, and particularly to the Secretary, Mr. Woodford, and to his principal assistant, Mr. Caselton. He would like to name all the members of the staff, but he knew that they would excuse him if he did not go through the list.

It was difficult to satisfy production engineers, but they were all very pleased with the way in which Mr. Woodford got to the point and satisfied the majority, and with the way in which he ran the organisation at Headquarters. Mr. Woodford, Mr. Caselton and their staff were all very pleasant people, which meant that the job was being well done.

Mr. E. N. Farrar, who seconded, reinforced what the President had said about Mr. Pryor's helpful assistance to the ordinary members of the Council, and also what he had said about the permanent staff.

The vote of thanks was carried by acclamation.

Mr. F. Woodifield proposed a vote of thanks to the President for his conduct of the meeting, and also for all the work which he had done for the last six months as President, and over the very many years for which he had worked for the Institution.

The vote of thanks was carried by acclamation.

The President, responding, thanked Mr. Woodifield for his kind words and the meeting for the reception given to them. Although it was not on the agenda, he felt that they should place on record the gratitude which they all felt for the wonderful work which was being done by the Chairmen, Secretaries and Committees of all the Sections and Regions. In going about the country in the last few months, nothing had heartened him more or given him a greater feeling of security than to see the good work which was being done and to talk to these men, who were doing a wonderful job of work during the day and giving their spare time to help the Institution. He wished also to thank very sincerely the Chairmen, Secretaries and members of the Standing Committees, who were laying a foundation or building up on a foundation which was going to give the Institution absolute security.

The meeting then terminated.

REPORT ON ELECTION OF MEMBERS TO COUNCIL 1957-58

IN accordance with Article of Association No. 34. there were 10 vacancies for elected Members of Council (eight Members and two Associate Members).

For the eight vacancies for elected Members 19 nominations were received. As a result of the ballot conducted in accordance with Article of Association No. 43, the following were elected :-

Mr. L. R. Evans	Mr. F. T. Nurrish,
Mr. E. F. Gilberthorpe	M.B.E.
Mr. F. Grimshaw, O.B.E.	Mr. L. S. Pitteway
Mr. H. B. Harris	Mr. R. H. S. Turner
Mr. R. E. Leakey	

For the two vacancies for the elected Associate Members, three nominations were received. The Associate Members elected were :-

Mr. G. V. Bevan	Mr. R. S. Clark

Ballot papers were circulated to 5,716 Corporate Members in the United Kingdom. Details of the voting issued by the Institution's Auditors are as follows :-

Eligible papers included in the ballot		1,424
Rejected :		
Incorrect number of votes recorded	26	
Papers not marked in ink ...	14	
Spoiled papers	3	
Envelopes unsealed	4	
Insufficiently stamped — return to G.P.O.	7	
Received from G.P.O. addressee not traced	3	
Papers received after closing date	28	
	—	85
		1,509

The full list of Council Members for the current year is published in the Journal.

REPORT OF COUNCIL

1st July, 1956 to 30th June, 1957

To be presented by the Chairman of Council at the

Annual General Meeting, 30th January, 1958

WHEN I reported to you last year on the results of our previous year's work, I was in a sense reporting for my predecessor in office, Mr. Pryor, who had been Chairman for the period under review. However, in submitting this report to you, I am not able to take quite such a detached view since it deals with my own period of office.

Council business

In spite of the various vicissitudes to which we have been subjected, for example, the side effects of the Suez crisis, increased postal charges, and so on, we have had, I feel, a very satisfactory year. The increase in the membership subscriptions took effect from 1st July, 1956, and met with a gratifying response from the membership. I am very happy to report that no more than 2% of the membership failed to renew their subscriptions as a result of the increase. This splendid response has enabled us to strengthen our financial position, to which I will refer later in this report.

Your Council have met four times during the year. The regular attendance of Council members and their close attention to the Institution's business has made my task as Chairman easy and enjoyable. We have had a number of forthright discussions on various aspects of the Institution's policy and although at times strong views have been expressed, it has been a source of great satisfaction to me that our meetings have been conducted in an atmosphere of great friendship.

It is our custom at each Council meeting, when we have dealt with the routine business, to give detailed consideration to a particular aspect of our affairs. During the past year we have discussed our policy *vis-à-vis* the Institution's National Conference which was held at Harrogate in June, 1957, to which I will refer again later in my report. We have also discussed "What is Meant by Practical Training ?" which was an extremely well-informed discussion. It was opened with a first-class address by Sir Walter Puckey, which was published in the April, 1957, Journal. At another meeting, Mr. E. W. Hancock, the President, gave a stimulating address which led to a most useful discussion of membership policy. On another occasion Regional finances and the expenditure of Institution funds in the Regions and local Sections was very closely examined.

Your Council decided that the Institution should again sponsor the forthcoming Production Exhibition, which is to be held at Olympia from 12th - 21st May, 1958. It was decided also that we should promote a Conference to be held at Olympia concurrently with the Exhibition, and a special committee has been set up to advise the Exhibition organisers and to plan the Conference. The Rt. Hon. The Earl of Halsbury, who was then President-Elect of the Institution, very kindly agreed to act as President of the Exhibition and Conference and to be Chairman of the Exhibition and Conference and to be Chairman of the Advisory Committee. Lord Halsbury has gathered around him a very strong Committee, but I will say no more about their work here as this will be anticipating next year's report.

Conferences

A number of conferences have been promoted by the Institution during the year in our Regions and Sections, and I will refer to them under the appropriate heading in the report.

The leading national event was the Conference held at Harrogate in June, 1957. The theme was: "Automatic Production — Change and Control", and this Conference was a successor to the Conference on "The Automatic Factory — What Does it Mean ?" which was held at Margate two years previously. Our plans for the Harrogate Conference were interrupted by the Suez crisis. The Conference Committee had prepared a substantial programme, extending over three days, but the coming of petrol rationing as a consequence of Suez caused the Committee to have some second thoughts. In the circumstances then prevailing, it was extremely difficult to try and forecast what conditions in industry would be like six months ahead when the Conference was due to be held and for a time your Committee considered that it might be advisable to abandon the Conference altogether. However, it soon became apparent that the situation was not likely to deteriorate and so it was decided to go ahead with the plans, but on a slightly reduced scale. The programme was curtailed to two days and, in the event,

the Conference proved to be highly successful. There were about 600 members of the Conference and the level of the Papers and discussions was very high indeed.

The principal criticism of the Conference afterwards was that too much work had been crammed into too short a time, as a result of the decision to reduce the length of the Conference by one day. The Papers presented to the Conference have been published in the Journal, and bound copies of the complete proceedings are now available.

Finance

You will find full details for the year published on pages 69 - 72 of the January, 1958, Journal : I am sure you have all studied them very closely. Your Finance and General Purposes Committee always gives the most detailed consideration to the Institution's finances. It became apparent 18 months ago that the substantial increase in postal charges would have a very adverse effect on our finances and would be aggravated by other symptoms of inflation which affect our Headquarters work. It was therefore decided to ask the membership to accept an increase in subscriptions immediately and the result of this is shown in our current accounts. Our surplus of income over expenditure for the year amounts to £8,530 as compared with only £843 in the previous year.

It is the view of your Finance Committee that the Institution ought to budget for annual surpluses of the order of 10% of the total income so that adequate provision can be made for the future of the Institution. The accounts under review, therefore, would seem to be a most promising start to such a policy. This figure of £8,530 for the current year is higher than might have been expected. In our original budget for the year, we anticipated a surplus of about £5,000. The increase is due to two reasons. Firstly, the income from membership subscriptions was slightly more than was expected and, secondly, we were without the services of an Education and Technical Officer at Headquarters for the greater part of the year, so that there was a saving on salary and expenses for this period.

I do not think that next year we shall show anything like such an adequate surplus. Already the Postmaster-General has announced further postal increases which are likely to cost us about £1,500 in the present year and £2,000 in a full year. Furthermore the Head Office staff has been substantially strengthened by the appointment of Mr. F. W. Cooper as Education and Technical Officer on 1st April, 1957, and by Mr. Ian King as Assistant Education and Technical Officer on 1st September, 1957. Mr. Cooper's appointment is not an additional one ; we have had a full-time Education Officer since 1948, but Mr. King's is an additional appointment to our Headquarters staff. Our various technical committees for many years have felt the urgent need for a full-time Technical Assistant at Headquarters, and your Finance Committee came to the conclusion that the time was now opportune for this appointment to be made.

Your Council are convinced that a positive and progressive policy is the right one to adopt. They are satisfied that Headquarters are run as economically as circumstances will allow. Any substantial economies in expenditure can only come from a severe curtailment of the Institution's activities. It is the view of the Finance and General Purposes Committee, fully supported by your Council, that such a step would be retrograde : if anything, the Institution must continue to expand its activities. How to expand the Institution's activities and services to the membership and budget for an annual surplus of 10% of the total income is a problem to which your Finance and General Purposes Committee is devoting very serious consideration.

May I now for a moment refer to some particular points of interest in the accounts. Firstly, to Income and Expenditure : establishment charges show a slight increase due to the new rating assessment on 10 Chesterfield Street and increased maintenance expenses. Administration expenses also show an increase. This is mainly due to the increased cost of postage and telephone and also, to a certain degree, is a measure of our expanding activities. Salaries show an increase over the previous year. This is partly due to extra staff at Headquarters, but is mainly due to a general increase in the level of salaries and wages paid to our staff. In seeking staff, particularly in the clerical grades, we find ourselves in competition with some of the great commercial and industrial organisations who have their headquarters in Mayfair. For obvious reasons we are not able to offer the same levels of pay and other inducements as some of these organisations, but we do try conscientiously to see that the level of wages paid to our Head Office staff is in keeping with the times.

Section expenses show an increase, mainly due to increased activities.

Journal costs

As a result of the very hard work of your Editorial Committee, expenditure on the Journal has been held to approximately the same figure as last year. The use of a thinner paper and other economies has enabled this to be brought about, but these sort of economies can only be effected once and I am afraid we must face the fact that the further increases in postage rates announced for October, 1957, and rises in the cost of paper and printing wages, will provide our Editorial Committee with some very serious problems in the near future.

Turning to our income, you will be pleased to note that the Journal receipts have shown a substantial increase as compared with the previous year. The Editorial Committee are to be congratulated on this very satisfactory achievement.

The other items of expenditure are self-explanatory and do not call for any special comment.

You will notice that revenue from renewal and arrears of subscriptions shows an appreciable increase over the previous year. This is, of course, due to the increased subscription rates.

There is no item shown in the accounts for recovery of income tax on covenanted subscriptions. This is because the claim had still not been met by the Inland Revenue when the accounts were closed and it is our policy not to take this refund of income tax into account until it is actually received.

The Income and Expenditure Account, of course, includes not only the U.K. but also the figures for our Councils and Sections outside the U.K. The summary of the Income and Expenditure Account published on page 70 shows how the figures are divided between the U.K. and the Councils and Sections outside the U.K. It will be seen that on the home account there is an excess of income over expenditure of £6,140 and that £2,390 is attributable to our Sections outside the U.K.

The Balance Sheet sets out the state of our assets and liabilities ; the proportion in the U.K. and outside the U.K. are shown in the next analysis.

The adoption of the accounts is a subject of a special item on the agenda and you will then have the opportunity to ask questions or to make comments.

Editorial Committee

The Journal

The substantial increases in postage rates announced by the Postmaster-General in January, 1956, imposed a heavy additional charge on the Journal. The Editorial Committee have given detailed consideration to every aspect of the production and distribution of the Journal and considerable economies have been made during the year. A less expensive paper has been adopted for both advertising and editorial pages, and some of the advertising rates have been increased, with especial reference to colour advertising. The Chairman of the Editorial Committee has also had a number of meetings with the Advertising Agents to discuss further economies and the possibility of widening the field of advertising, always, of course, bearing in mind the professional standing of the Institution and the desire to produce a high quality Journal.

It is interesting to note that the sales of the Journal are showing an upward trend ; the sales figures for January, 1957, are approximately double those for January, 1956. A great part of this increase is due to subscriptions taken out in Russia and China, and this is one of a number of indications that the sphere of influence of the Journal is spreading.

Advertising

The Suez emergency resulted in a general recession in all fields of advertising, and a number of firms withdrew from the Journal at this time. The Committee is pleased to report that a number of these cancellations have now been rescinded and the general prospect appears to be healthy. It would be dangerous, however, to assume an attitude of complacency in this respect, as competition is increasing daily. In the Committee's opinion, it behoves every member of the Institution who is in a position to do so to influence his own firm to take some advertising space in the Journal, however small. It is very important, too, when sending enquiries to advertisers to mention the Institution's Journal.

General Remarks

While the high standard of technical material published in the Journal is being maintained, the Committee is pleased to report that a number of authoritative leading articles on production engineering policy are being contributed, by invitation, from prominent industrialists at home and abroad.

The Institution continues to receive a gratifying amount of favourable publicity and is constantly approached by the technical and lay press for permission to use Papers presented to Sections, or material used in one or other of the Institution publications.

With the introduction of a stronger type of envelope for despatching the Journal, complaints of Journals being received in a damaged condition have virtually disappeared.

The Chairman of the Editorial Committee during the year was Mr. John Mitford Brice.

Papers Committee

The Papers Committee continue to concentrate their efforts on increasing the supply of high grade Papers for publication in the Journal, and on making arrangements for the presentation of the Institution's Named Papers. The Chairman maintains regular contact, by personal correspondence and through Corresponding Members, with Section and Region Chairmen and Secretaries, and much help and many useful suggestions are received from this source.

The Chairman has also been in touch with a number of research organisations in the United Kingdom, with a view to obtaining for exclusive publication in the Journal original material dealing with the latest developments of interest to engineers. Friendly relations have now been established with the National Physical Laboratory and the Mechanical Engineering Research Laboratories at East Kilbride, and a number of other research bodies have expressed their willingness to co-operate.

Named Papers

During the year under review, four Named Papers have been presented, as follows :-

The 1956 *Sir Alfred Herbert Paper* was presented at the College of Science and Technology, Manchester, on 14th November, 1956, by Dr. B. V. Bowden, whose subject was "The Development of Technological Education in Europe, America and England". This was a highly successful occasion, and the full text of the Paper appeared in the February, 1957, Journal.

The 1956 *Viscount Nuffield Paper* was presented at the University of Bristol on 17th October, 1956, by Dr. Grey Walter, who spoke on "Thinking

Machines". There was a capacity attendance for this meeting, and the ensuing discussion had to be brought to a close because of time limitations. The full text of the Paper was published in the January, 1957, Journal.

The 1956 *George Bray Memorial Lecture,* presented in Sheffield on 18th March, 1957, by Mr. Stafford Beer, who spoke on "The Scope for Operational Research in Industry", attracted an audience of over 600 to the Sheffield City Hall — the largest attendance so far for a Named Paper. The full text of the Paper was published in the May, 1957, Journal.

The 1957 *Lord Sempill Paper* was presented at the fifth Aircraft Production Conference at Southampton University by Herr K. Frydag. This was a most interesting Paper and Herr Frydag chose as his subject "Concentration in Aircraft Development". The full text of the Paper appeared in the March, 1957, Journal.

Medal Awards, 1955 - 1956

The Committee carefully considered the award of Institution Medals for the best Paper presented to a Section by a Member, by a non-member, and by a Graduate (The Hutchinson Memorial Award) for 1955 - 1956, and regretfully concluded that in view of the small number of Papers eligible, and the fact that none of them, in the Committee's opinion, reached the required standard, no awards should be made. The appropriate recommendation was accordingly made to the Council.

The Committee are aware that some criticism may be forthcoming as a result of this action. They are deeply sensible of their responsibilities in making recommendations for these awards, and feel strongly that if the awards are to have any real meaning, the standard of Papers must be kept as high as possible. The Committee consider it preferable to make no award rather than to make an award to a Paper which, although it may be the best of those submitted, is still, in their opinion, not an outstanding contribution at the level at which awards are made.

The Chairman of the Papers Committee during the year was Mr. A. A. Francis.

Education and Membership Committees

Appointment of Education Officer

When Mr. H. W. Badger resigned his appointment from the Institution on 31st August, 1956, your Education Committee was faced with the difficult task of finding a successor who would be able to give the fullest possible effect to the Institution's education policy. The Education Committee feel that in Mr. F. W. Cooper, who was appointed on 1st April, 1957, we have an Education Officer whose considerable experience both in industry and in education will be of the utmost value to the Institution.

Changes in Membership Examinations

The most important task confronting the Education Committee during the year was the reconstruction of the Associate Membership Examination. This has been under review for a number of years in order to give effect to the Council's policy of "Broadening the Base" of the membership of the Institution. Substantial progress was made during the year and a draft plan was submitted to the Council of the Institution in July, 1957. A comment on the plan was prepared by Mr. R. Ratcliffe, M.B.E., Chairman of the Committee, and was published in the July, 1957, Journal. Your Council adopted the plan in general terms and the Education Committee are now engaged in the detailed work of preparing syllabuses and draft examination papers. It is hoped that full details of the new examination will be published in this present year. The examination in its new form will be a substantial step forward and will do much to establish the Institution as the leading authority on production technology and management.

Summer School

The Summer School was held at Ashorne Hill, near Leamington Spa, from the 25th - 29th July, 1956, the theme being "Education for Automation". The School attracted a number of leading personalities in the education world to attend as "students".

Higher Technological Education

The National Council for Technological Awards, under the Chairmanship of Lord Hives, is making a substantial contribution to the development of higher technological education in this country. The Institution's particular interest is in the work of the Board of Engineering Studies under the Chairmanship of Sir Walter Puckey, a Past President of the Institution, and it is gratifying to see that this new Board is setting such high standards for the new Colleges of Advanced Technology. It is inevitable, with the rapid expansion in technology, that standards of education and training for young engineers must keep in step with the times. It is gratifying to notice that considerable emphasis is being placed on the development of facilities for the teaching of production engineering in the Colleges of Advanced Technology.

The ultimate success of these schemes depends on the fullest co-operation from industry. It would be unreasonable of industry to expect an ever-increasing stream of highly skilled technologists and engineers unless industry itself is prepared not only to release their young men for sandwich courses and other study periods, but also to encourage some of their senior executives to give up some of their own time to teaching in the technical colleges. It is very important, too, that industry should encourage full time teachers in technical colleges to visit factories and keep themselves in touch with the best current production practice.

Associate Membership Examination, 1957

The examination took place in May, 1957. A total of 270 candidates sat the examination, which

was 41 more than in the previous year. Approximately 61% of the candidates were successful in passing the examination, a higher percentage than in previous year (see page 57).

Membership

The number of applications for membership continues at a steady level and it is satisfactory to note an increase of membership in the grade of Member and Associate Member during the year.

Although we have an age limit for Students and Graduates, we have over the past years made substantial concessions to Students and Graduates reaching the age limit, on account of compulsory military service and other factors. A close examination of the position earlier in the year made it clear that we had a considerable number of Students and Graduates on the register who obviously had no intention of attempting to qualify for a higher grade of membership. It was decided, therefore, to remove a large number of these names from the register.

Your Finance and General Purposes Committee also consider that we should be more strict in the removal from the register of members of those who do not renew their annual subscription within the prescribed period.

The detailed figures below show the state of membership at the end of June, 1957, with a comparative figure for the previous year. You will see that the net effect of our activities is a very minor reduction in the total membership. However, the trend of applications received at Headquarters indicates not only that the membership will begin to rise again in the near future, but that the quality of new entrants will also be higher.

	June, 1957	June, 1956
Honorary Members	6	8
Members	1,708	1,685
Associate Members	5,037	4,979
Associates	146	158
Graduates	2,248	2,230
Students	1,131	1,248
Affiliated Firms	244	234
	10,520	10,542

During the year, the Chairman of the Membership Committee was Mr. F. Woodifield and the Chairman of the Education Committee was Mr. R. Ratcliffe, M.B.E.

Research Committee

The Research Committee and their sub-committees have been extremely active during the year.

A successful three-day Convention was organised at Leamington Spa in September, 1956, by the Materials Handling Sub-Committee.

The Syllabus and Examination Working Group of the Materials Handling Sub-Committee completed their report, and this was submitted to the Education, Membership and Research Committees for consideration.

The Formation of Divisions Sub-Committee held a meeting to investigate the desirability of setting up within the Institution a specialist group in Materials Handling. As a result of their deliberations, the Sub-Committee recommended that the existing Materials Handling Sub-Committee be given the status of a specialist group and, after consideration by the Finance and General Purposes Committee, this recommendation was finally approved by Council at their meeting in April.

The new Materials Handling Group held their inaugural meeting on 21st May, under the Chairmanship of Mr. A. G. Hayek. A Sub-Committee was formed for the purpose of drafting the conditions of membership of the Group, and tentative plans were made for the organisation of another three-day Convention on Materials Handling in October, 1957.

The Material Utilisation Sub-Committee, under the Chairmanship of Mr. R. N. Marland, completed the collation of the Notes for Guidance which had been prepared by the four Panels of the Sub-Committee, for circulation to the Regions, Sections and affiliated companies, The Sub-Committee anticipated that within a few months they should receive many valuable case studies on the use of raw and process materials in the engineering and allied industries, for inclusion in the final report.

Publication of the Directory of Sources of Information for the Production Engineer has been somewhat delayed, owing to unforeseen circumstances.

The Sub-Committee on Control of Quality, which was set up under the Chairmanship of Mr. R. K. Grunau, have made good headway during the year with the preparation of their report. Half of this is now in final draft form and the Sub-Committee hope to complete the report early in 1958.

The new Joint Research Committee, under the Chairmanship of Mr. B. H. Dyson, continues to provide the focal point for liaison between our own Institution and the Institute of Cost and Works Accountants. The two Sub-Committees of the Joint Committee — one set up to investigate electronics and kindred modern developments as applied to process loading, under the Chairmanship of Mr. C. E. Sutton ; and the other to investigate the efficient use of shift-working in industry, under the Chairmanship of Mr. B. G. L. Jackman — are continuing with their investigations. These two Sub-Committees feel that the appointment of an Assistant Technical Officer at Headquarters, which is imminent, will considerably facilitate their research.

Mr. F. G. S. English was Chairman of the Research Committee during the year. Mr. English has long been connected with the work of the Research Committee and his valuable contribution is very much appreciated.

Standards Committee

The Standards Committee have continued their routine work of commenting on draft British Standard specifications and nominating Institution

representatives to serve on British Standards Institution Technical Committees.

Following the Standards Committee's recommendation for a revision of British Standard 1886 on Terms and Definitions for Single Point Cutting Tools, the British Standards Institution have reconstituted their Technical Committee MEE/6/3 for the purpose of investigating this subject. The Institution will be represented on this Technical Committee by Dr. D. F. Galloway, Mr. R. Kirchner, Mr. J. C. Z. Martin and Mr. G. V. Stabler.

The Sub-Committee on Unit Heads and Platens, under the Chairmanship of Mr. J. A. W. Styles, prepared detailed recommendations for investigating the standardisation of Unit Heads. The Committee submitted these findings to the British Standards Institution and, as a result of these recommendations, the British Standards Institution have set up a new Sub-Committee MEE/6/21 under the title "Unit Heads" for dealing with the project. The Institution will be represented on this Sub-Committee by Mr. A. A. J. Francis, Mr. J. A. W. Styles and Mr. J. H. Winskill.

The Committee felt that British Standard 861, Part I, which is confined to specifying electrical performance of limit switches on machine tools, should be extended to include the consideration of mechanical performance and dimensions. With a view to submitting recommendations along these lines to the British Standards Institution, the Sub-Committee on Unit Heads are preparing a report on the subject.

Approval was granted by the Finance and General Purposes Committee for the installation of a new records system at the Institution and plans are in progress for the implementation of this decision.

The I.Prod.E./B.S.I. Joint Standing Advisory Committee on the Use of Standards in Industry were responsible for organising the third Annual Conference of Standards Engineers which was held on 9th May, 1957, at Church House, Westminster. The Chair was taken by the Chairman of the Standards Committee and the Conference was attended by about 200 delegates. The Joint Standing Advisory Committee, which provides liaison between the Institution and British Standards Institution, continues to hold regular meetings.

The Chairman of the Standards Committee during the year was Mr. H. Stafford and his energetic direction of the Committee has proved of immense value.

Hazleton Memorial Library Committee

The Library had a busy year during which inquiries were received on a wide range of subjects. The Conference on "Problems of Aircraft Production" resulted, as usual, in a number of inquiries, including some from firms overseas, and there was a noticeable increase in the inquiries about computers, punched cards and machine tool control. However, it is probable that more inquiries were received about education and training than about any other single subject — understandably in view of Governmental action and recommendations. In fact, technical education was the theme of the year. The constancy of inquirers was overtopped by that of authors, whose enthusiasm for the fascinating subject shows no sign of waning. The subject of "introducing new methods or technical changes" (a concomitant of "automation"), in all its aspects, sociological, technical, and educational, also received a great deal of attention from authors and inquirers. A suggested study of a minor branch of this quasi-technical subject reveals two groups of people who, so it is suggested, have to be placated, smiled at, and talked down to, and between whom the professional engineer leads a troubled existence: the "Workers" and the "Management" (or Board of Directors) both of which (if we are to believe all we read) live in an intellectual half-world.

Fewer inquiries were received than during the previous year, when the publicity accorded to the National Conference on "The Automatic Factory" was having its full effect. However, there were 64% more inquiries than during 1954 - 1955, and very many more bibliographies and reading lists were compiled. This prosperity is attributable to the growth of the Institution and to the efforts of he Library Commitee to publicise the Library's services.

Region and Section Activities

Region and Section activities have gone from strength to strength; nearly 350 Section lecture meetings and seven Regional lecture meetings have been held in the U.K. and over 50 lecture meetings have been held in Sections outside the U.K. In addition, many successful social functions have been arranged and also many interesting works visits and similar activities have taken place.

The Regional organisation on the whole seems to be functioning well, though in some Regions geographical considerations do not permit such successful working as in the more closely-knit Regions.

The Midlands Region promoted a very successful one-day Conference in Birmingham in May, 1957, the subject being "Tooling — Tomorrow's Production".

Another successful Conference which was held was that arranged by the North Midland Region and took place at Peterborough on 2nd June, 1956. The theme of the Conference being "Aspects of Automation".

The Southampton Section promoted the fifth Annual Conference on "Problems of Aircraft Production", which was held at the University of Southampton in January, 1957. Once again this was a highly successful event and was, in fact, over-subscribed.

These conferences have all been reported in the Journal.

Regional one-day conferences, where members with common interests can exchange views and discuss local problems, can be extremely valuable and it is hoped that more Regions will, in due course, include such activities in their programme.

The Annual Conference of Region and Section Honorary Secretaries was held at Head Office in May, 1957. There was a higher attendance than in previous years and valuable discussions took place on the administrative problems of the Institution. This Conference is a very great help in maintaining the good relations which exist between Honorary Secretaries and the Institution Head Office staff.

The activities of the Graduate Sections have been well to the fore, the most recently formed Sections being at Rochester, Kent; and Melbourne, Australia. The Graduate Representatives Conference was held in Birmingham and was well attended, the theme being "Engineering for Existence". Both the Halifax Graduate Section and the London Graduate Section continue to hold highly successful week-end schools.

A number of members from Sections throughout the Commonwealth have visited Headquarters during the year. At the same time, a number of members from Great Britain have taken the opportunity of visiting Sections overseas on their business trips abroad. These personal contacts are invaluable in maintaining relations with our members all over the world.

It is in the Regions and Sections that the great bulk of the Institution's profesional work is done. Our extensive network of local Sections in the U.K. means that very few members indeed are out of reach of a centre of Institution activity.

On behalf of the Council, I should like to express our very sincere appreciation to all those members who serve on Section Committees and accept responsibilities on these committees, and who see that the high level of our Institution activities is maintained not only in volume but in quality. I would like particularly to mention the Honorary Secretaries. They carry out a substantial burden of duties on our behalf and I am afraid we sometimes tend to take their services for granted. Many of us are guilty of making their duties unnecessarily onerous by neglecting to reply to our correspondence, or by not letting them know promptly our requirements when conferences and other activities are being arranged.

A professional institution is a co-operative organisation: its strength lies entirely in the extent to which members are prepared to contribute to its activities and to give of their own free time to the promotion of its objects. We are well served in our Institution. In addition to the work of our Committees and Officers, a very large number of members of the Institution give service in other ways: they prepare Papers, they comment on draft Standard specifications, they serve on Boards of Governors of Technical Colleges and on Engineering Advisory Councils — and in numerous other ways they help not only the Institution but the community at large. I would commend all our younger members to study the example set by those many senior members whose services in the past have brought the Institution to its present influential position. There is a tremendous satisfaction to be gained in public service of this kind and, not least of, the rewards is the warm friendships that are made.

Honours

Her Majesty the Queen has been graciously pleased to confer honours on members of the Institution whose names are given below :-

KNIGHT BACHELOR	—	W. Scott
O.B.E.	—	C. D. Alder
M.B.E.	—	W. H. Hopkins
		R. G. Winton

Obituary

It is with deep regret that the deaths of 53 of our members must be recorded. Their names have been published in the Journal.

Headquarters Staff

There have been few changes in the senior staff structure at Headquarters. We have a team of competent administrators who between themselves have a very substantial knowledge of every detail of the Institution's life and history. Mr. Cooper, to whose appointment as Education Officer I have already referred, is a most welcome addition. I am happy to say that there is the closest spirit of co-operation in our Head Office and it must be a great source of satisfaction to the members of the Institution to know that they are served by staff who have a very keen sense of responsibility.

It is indeed encouraging to know that we have such an enthusiastic staff at Headquarters, and I am sure you will join with me at this, our 35th Annual General Meeting, in expressing my appreciation of the splendid way in which Mr. Woodford and his colleagues continue to serve the Institution.

Awards

It is with pleasure that I report the award of the 1957 Schofield Travel Scholarship to Mr. J. Parson, Graduate, Senior Methods Production Controller at Solartron Engineering Ltd. Mr. Parson proposes to spend three months in America, studying manufacturing techniques of small electro-mechanical mechanisms.

The President

I have had the great honour and privilege of serving as Chairman of Council under Mr. E. W. Hancock, M.B.E., the President of the Institution. Mr. Hancock was Chairman of the Institution's Council as long ago as 1931 and his devotion to the Institution and all it stands for must be a source of great inspiriation to the membership. His accumulated knowledge and wisdom have been available to me at all times and I should like to express my personal gratitude to him for his kindly encouragement. During his period of office he travelled widely and attended numerous Institution functions all over the country. The Institution has been extremely fortunate over the years in its choice of Presidents and Mr. Hancock's name will be among the greatest of them.

In asking you to receive this report of your Council for the year ended 30th June, 1957, I am sure you will do so with every confidence that your Council is conscientously and effectively managing the affairs of the Institution on your behalf.

THE INSTITUTION OF PRODUCTION ENGINEERS

SUMMARY OF INCOME AND EXPENDITURE ACCOUNT

For the Year to 30th JUNE, 1957

	£	£		£
Expenditure in the United Kingdom	77,642		**Income** in the United Kingdom	83,782
Less Cash remitted by Councils and Sections outside the United Kingdom	1,143		**Income** in Councils and Sections outside the United Kingdom	4,830
		76,499		
Expenditure in Councils and Sections outside the United Kingdom	2,440			
Add Cash remitted to the United Kingdom ...	1,143			
		3,583		
Excess of Income over Expenditure in the United Kingdom	6,140			
Excess of Income over Expenditure in Councils and Sections outside the United Kingdom ...	2,390			
		8,530		
		£88,612		£88,612

ANALYSIS OF ASSETS AND LIABILITIES at 30th JUNE, 1957

	United Kingdom £	*Outside U.K.* £		*United Kingdom* £	*Outside U.K.* £
Accumulated Funds and Surplus	47,624	8,235	**Fixed Assets**		
Melbourne Prize Account—Australia		61	Freehold Premises	38,355	
Current Liabilities			Furniture, Fittings and Plant	4,397	248
Sundry Creditors	10,056	356	Fund Investments	1,100	
Subscriptions received in Advance	309	195		43,852	248
			Current Assets		
			Sundry Debtors, Deposits and Stocks	10,264	92
			Investments—South Africa		2,480
			Cash at Bank and in Transit		
			United Kingdom	3,873	
			Australia		2,915
			Bombay		439
			Calcutta		1,067
			New Zealand		567
			South Africa		592
			Canada		447
	£57,989	£,8847		£57,989	£8,847

THE INSTITUTION OF PRODUCTION ENGINEERS

INCOME AND EXPENDITURE ACCOUNT for the Year ended 30th JUNE, 1957

1956					1956				
£	£		£	£	£	£		£	£
		To **Establishment Charges**					By **Subscriptions**		
969		Rates	1,146		31,978		Renewals and Arrears	40,706	
1,392		Light, Heat and Cleaning ...	1,546		333		Transfers	487	
653		Repairs and Renewals	543		1,085		New	870	
—	3,014		—	3,235	4,173		Overseas	4,573	
		,, **Administration Expenses**			437		Entrance Fees	422	
2,296		Postage and Telephone	2,628				Registration and Miscellaneous		
4,271		Printing and Stationery	4,435		964		Fees	1,390	
		Professional Charges and Insur-					Recovery of Income Tax on		
559		ance	343		2,283		Subscriptions	—	
200		Audit	250		—	41,253		—	48,448
		Travel, Entertaining and Meet-			154		,, **Interest**		211
2,120		ings (other than Sections) ...	2,366		36,805		,, **Journal Receipts**		39,156
75		Miscellaneous	85		603		,, **Sale of Proceedings**		359
—	9,521		—	10,107	108		,, **Miscellaneous Receipts**		120
	18,940	,, **Salaries**		20,468	137		,, **Summer School**		—
		,, **Section Expenses**			160		,, **Examinations**		274
2,062		United Kingdom	2,161		—		,, **Annual Dinner, 1956**		44
2,321		Overseas (Audit Fees £83) ...	2,415						
1,370		Central Services	1,790						
—	5,753		—	6,366					
		,, **Journal**							
30,840		Printing	30,253						
5,137		Postage and Envelopes	5,782						
259		Reporting	169						
—	36,236		—	36,204					
	313	,, **Institution Papers**		310					
	406	,, **Hazelton Memorial Library** ...		386					
	319	,, **Schofield Scholarship**		299					
	119	,, **Donations and Subscriptions** ...		137					
	679	,, **Conferences**		863					
		,, **Miscellaneous**							
73		Annual Dinner, 1955	—						
1,049		Year Book	—						
—		Summer School, 1956	20						
214		Press Cuttings	79						
405		Bank Interest and Charges ...	185						
—	1,741		—	284					
		,, **Provisions**							
	336	Depreciation—Furniture and Fit-							
		tings		923					
	500	,, **Renovations Reserve**		500					
		,, **Balance**—Excess of Income over							
	843	Expenditure carried down ...		8,530					
	£79,220			£88,612	£79,220				£88,612

APPROPRIATION ACCOUNT

1956				1956			
£		£		£		£	
18,581	To Balance carried forward		27,111	17,738	By Balance at 1st July, 1956		18,581
				843	,, Excess of Income over Expenditure brought down		8,530
£18,581			£27,111	£18,581			£27,111

THE INSTITUTION OF PRODUCTION ENGINEERS

BALANCE SHEET as at 30th JUNE, 1957

1956					1956				
£	£		£	£	£	£		£	£
		Accumulated Funds and Surplus					**Fixed Assets**		
25,000		The Viscount Nuffield Gift	25,000		35,000		Freehold Premises: At cost		35,000
500		The Lord Austin Prize Fund ...	500				Freehold Premises: Cost of Alterations and Equipment, *less* Donations, Reserves, etc.:		
100		The Hutchinson Memorial Fund ...	100				Balance at 1st July, 1956	3,394	
500		The George Bray Memorial Fund ...	500				*Less* Receipts during year	39	
	26,100			26,100	3,394				3,355
	1,000	Renovations Reserve		1,500			Furniture, Fittings and Plant at the net amount standing in the Institution's books at 30th June, 1948	1,531	
	1,106	Life Subscriptions: *Less* amount transferred to Income and Expenditure Account		1,148			Additions *less* Sales	7,996	
	18,581	Income and Expenditure Account ...		27,111				9,527	
	46,787			55,859			*Less* Depreciation to date	4,882	
	60	Melbourne Prize Account		61	4,773				4,645
		Current Liabilities					Fund Investments at cost: as scheduled		
6,856		Sundry Creditors	10,413		1,100		(Market Value £873)		1,100
467		Subscriptions Received in Advance ...	503			44,267			44,100
		Bank Overdraft: *Less* Sections and					**Current Assets**		
5,611		Cash Balance	—		13,334		Sundry Debtors, Deposits and Stocks...	10,356	
	12,934			10,916	—		Cash at Bank and in Hand	9,900	
					2,180		United Building Society — Deposit (South Africa)	2,480	
						15,514			22,736
£59,781				£66,836	£59,781				£66,836

E. W. HANCOCK, M.B.E., *President.*

H. G. GREGORY,
Chairman of Council and Finance Committee.

W. F. S. WOODFORD, *Secretary.*

Report of the Auditors to the Members of The Institution of Production Engineers

We have obtained all the information and explanations which to the best of our knowledge and belief were necessary for the purposes of our audit. In our opinion proper books of account have been kept by the Institution so far as appears from our examination of those books. Audited Balance Sheets and Accounts have been received from each of the Councils and Sections outside the United Kingdom, and these have been incorporated in the above Balance Sheet and annexed Income and Expenditure Account. We have examined the above Balance Sheet and annexed Income and Expenditure Account which are in agreement with the books of account audited by us and the audited Accounts of the Councils and Sections outside the United Kingdom supplied to us. In our opinion and to the best of our information and according to the explanations given us the said Accounts give the information required by the Companies Act, 1948, in the manner so required and the Balance Sheet gives a true and fair view of the state of the Institution's affairs as at 30th June, 1957, and the Income and Expenditure Account gives a true and fair view of the excess of income over expenditure for the year ended on that date.

20, Bloomsbury Square,
London, W.C.1.

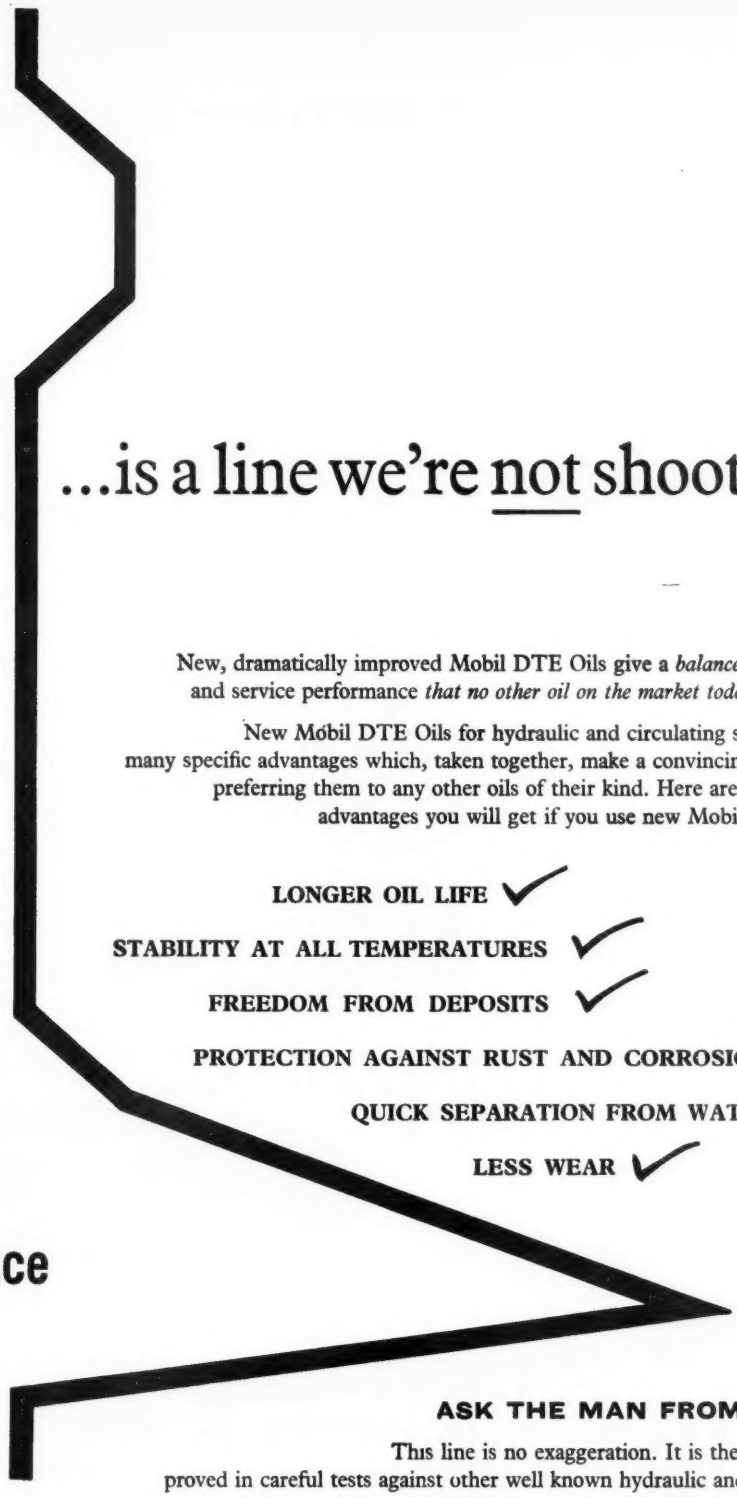
21*st October*, 1957.

GIBSON, APPLEBY & CO.,
Auditors.
Chartered Accountants.

THE INSTITUTION OF PRODUCTION ENGINEERS

INVESTMENTS AT COST, 30th JUNE, 1957

	£	£
The Lord Austin Prize Fund		
£95 8s. 5d. 3½% War Stock	100	
£575 8s. 3d. London County 3% Consolidated Stock, 1920	400	
		500
The Hutchinson Memorial Fund		
£95 8s. 5d. 3½% War Stock		100
The George Bray Memorial Fund		
£775 0s. 9d. London County 3% Consolidated Stock, 1920		500
(Market Value £873 9s. 5d.)		£1,100



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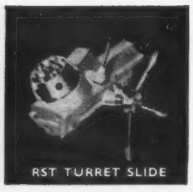
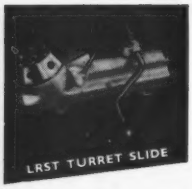

RST TURRET SLIDE

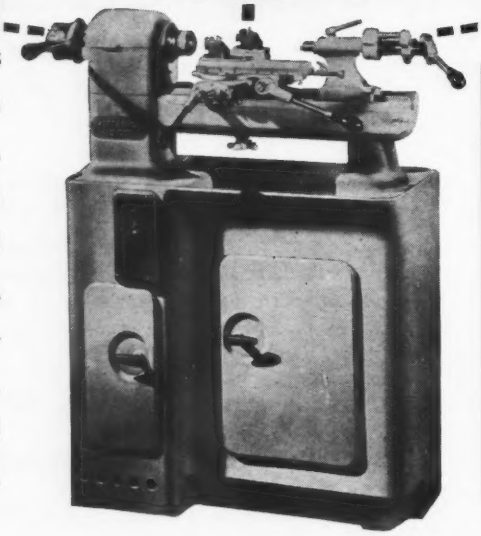
TSC TAILSTOCK

LPH HEADSTOCK

CWP CUT-OFF SLIDE


LRST TURRET SLIDE

TUC TAILSTOCK



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1957/58

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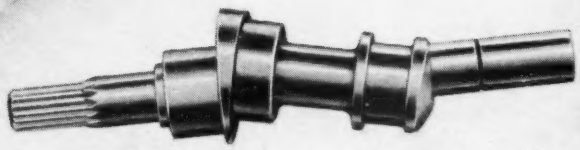

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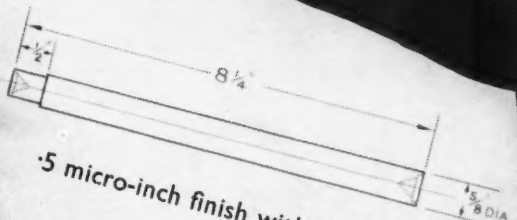

·5 micro-inch finish with standard grinding wheel

"As you will see from the sample, the result obtained is quite excellent and after several weeks of research with fine grade wheels for finishing only, we are very delighted to obtain such a good result from the standard type of wheel."

an unrequested opinion from

I. L. BERRIDGE & CO LTD

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KG MACHINE TOOLS

MODEL KL 4" x 18" HIGH PRECISION CYLINDRICAL GRINDER

ONE OF THE NEWALL GROUP

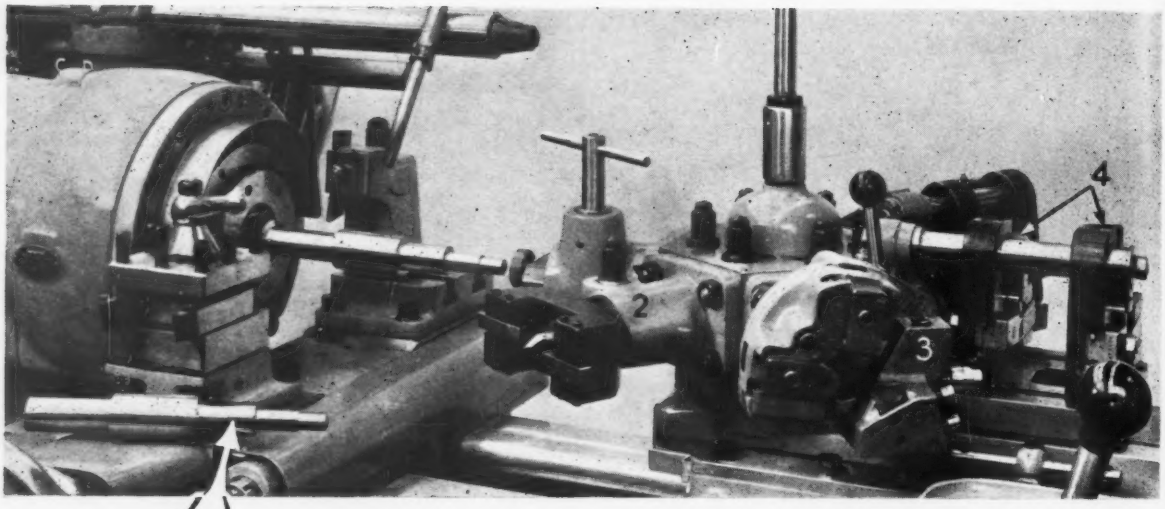
available with self-contained internal grinding attachment and 'TRUMATIC' wheel-wear and size compensator, is one of a range of superior quality grinding machines manufactured by KEIGHLEY GRINDERS (MACHINE TOOLS) LTD

full details on request to

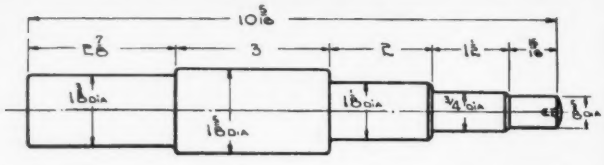
NEWALL GROUP SALES LIMITED

PETERBOROUGH PHONE 3227-8-9 KEIGHLEY PHONE 4294

Maximum Production Special Tool Layouts



CENTRE SHAFT



1¾ dia. Steel Bar, En.8
40 Ton Tensile Steel

Tungsten Carbide and
H.S. Steel Cutting Tools

Ward

No. 7 CAPSTAN LATHE

FITTED WITH 2 IN. AIR AUTO. BAR CHUCK AND AIR BAR FEED

DESCRIPTION OF OPERATION	Tool Position		Spindle Speed R.P.M.	Surface Speed Ft. per Min.	Feed Cuts per inch
	Hex. Turret	Cross-slide			
1. Feed to Stop and Centre Drill	1	—	1000	—	Hand
2. Start Turn 1⅛" and ¾" dia.	2	—	1000	460	Hand
3. Support and Double Turn 1⅝" and 1⅜" dias.	2	Front	1000	460	152
4. Tangential Turn 1⅛" dia.	3	—	1000	460	133
5. Multi Turn ¾" and ⅝" dias.	4	—	1000	295	133
6. Radius, Chamfer and End (Multi-Toolholder)	5	—	1000	425	Hand
7. Support and Part Off	6	Rear	1000	360	Hand

Floor-to Floor Time: 3¼ mins. each

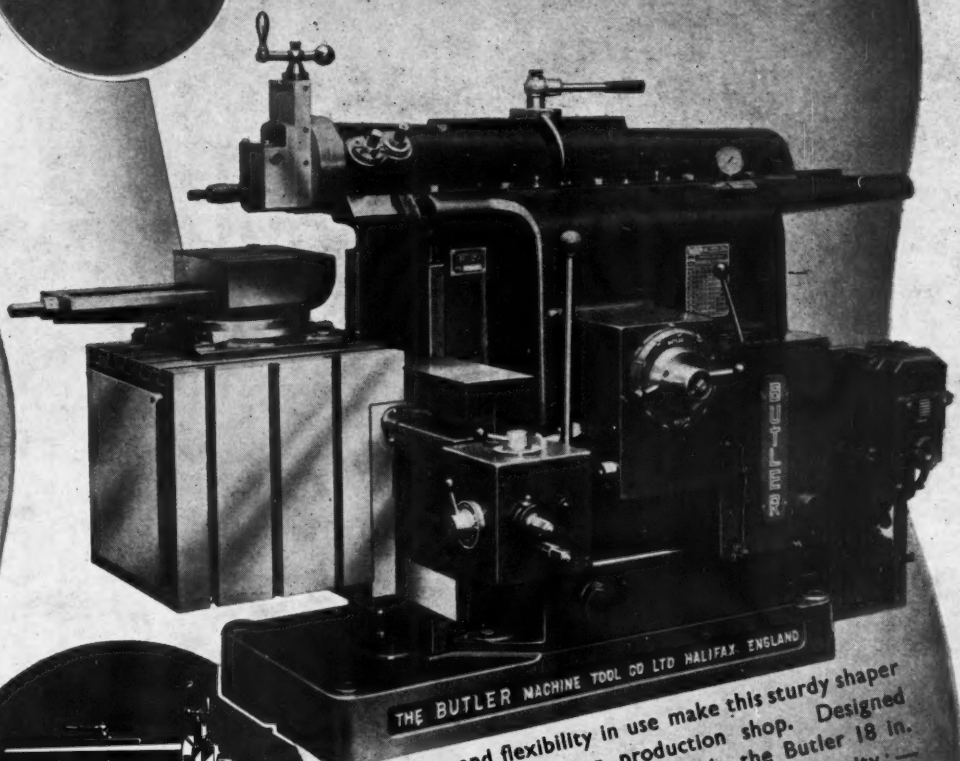
H·W·WARD & CO LTD

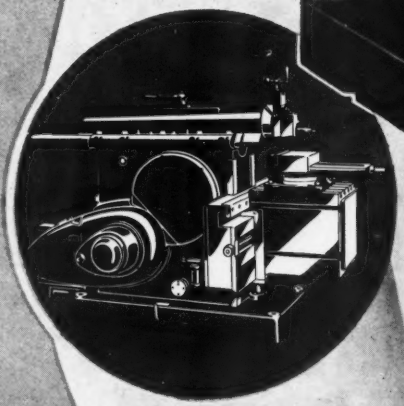
SELLY OAK
BIRMINGHAM 29
TELEPHONE SELLY OAK 1131

W653

Butler

18" SUPER SHAPER





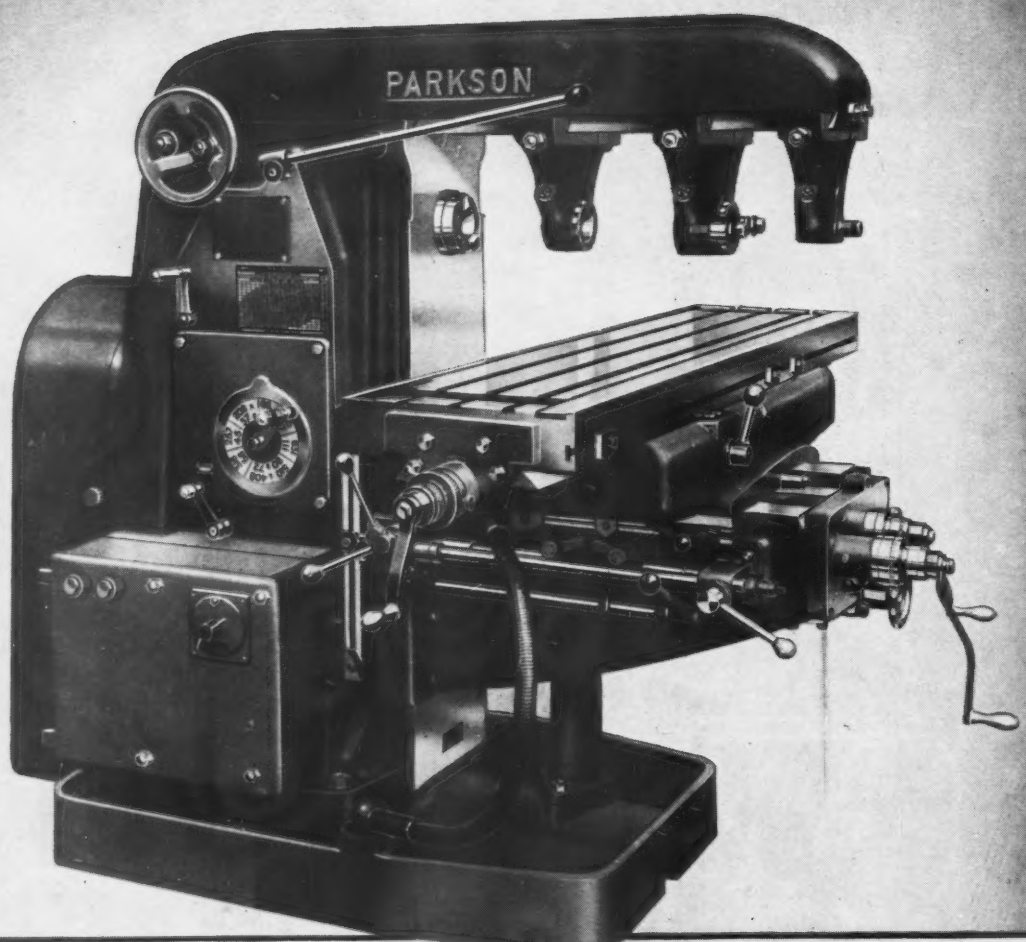
Economy and flexibility in use make this sturdy shaper ideal for toolroom or production shop. Designed for smooth operation at all speeds, the Butler 18 in. stroke Super Shaper has the following capacity:—

Table top 18 in. long x 17½ in. wide
Table side 18 in. long x 17 in. wide
Table travel 20 in. horizontal
Table admits 12 in. under toolbox
Range of speeds 15-150 cycles per minute.

The BUTLER MACHINE TOOL Co. LTD.
HALIFAX ENGLAND
FOR PRECISION PLANERS SHAPERS SLOTTERS

B 301

PARKSON Millers



3NP PLAIN MILLER

J PARKINSON & SON (SHIPLEY) LTD

SHIPLEY YORKSHIRE
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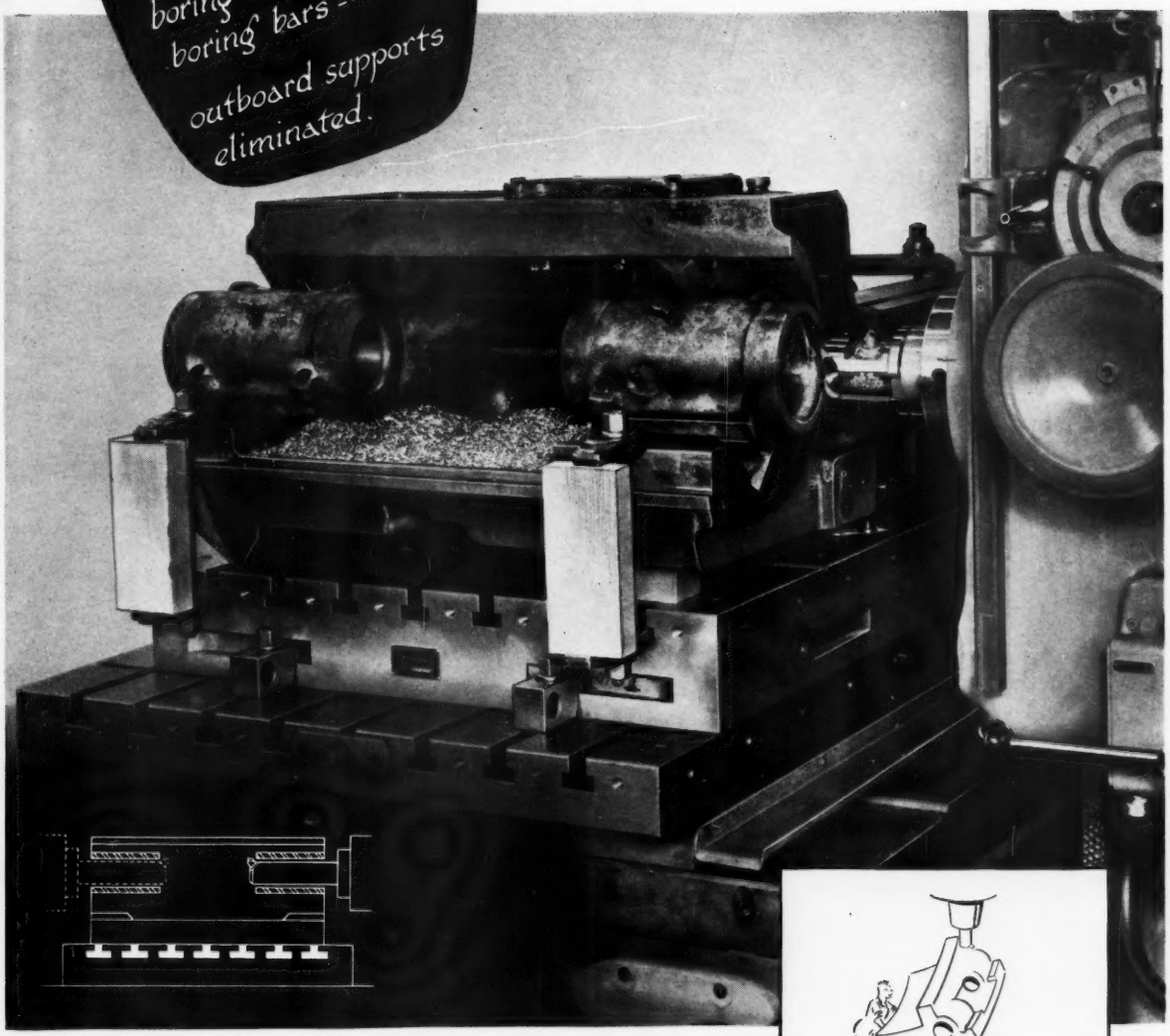
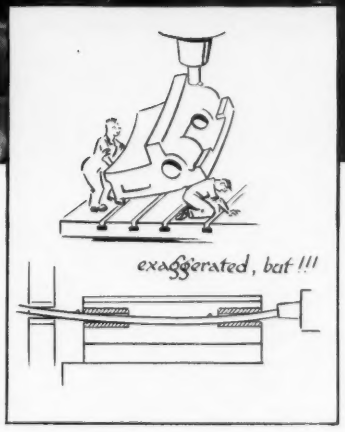
P3518

DEVLIEG method ---- index table permits in-line boring with short rigid boring bars ----- outboard supports eliminated.





An opensided machine.
Jigless boring method for the toolroom or for production.
Constant horse-power at all speeds.
Automatic precise positioning of table and spindle head.
Automatic depth control.
Power-operated tool lock.
Precise co-ordinate location of work and spindle by centralised push button control.
Capable of milling up to the full horse-power of the spindle motor.

The smallest of the range of DeVlieg Jigmils, the 2B/36, is now built by us in a new specially equipped plant. Its capacity is 24″ (vertical); 36″ (horizontal) and has a 2½″ dia. spindle.

ALFRED HERBERT LTD., COVENTRY – FACTORED DIVISION, RED LANE WORKS

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ASQUITH

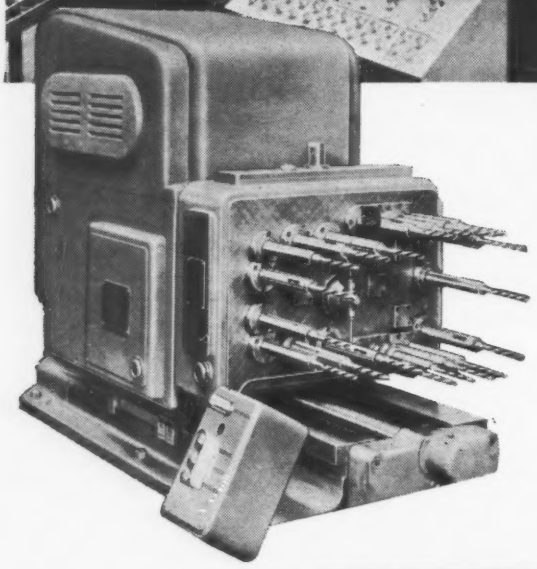
UNIT TYPE MACHINES

fully engineered for high-output production

Individual Head Machines

Multi-Way Machines

Rotary Table Transfer and In-line Transfer Machines



The illustration above shows a 17-station transfer line for machining automobile cylinder heads, both 4 and 6 cylinder types being handled on the same machine.

This is a typical example of the application of Asquith Unit Heads to the design of high output machine tools. Units from ½ H.P. upwards are utilized individually or in combination and mounted for horizontal, vertical or angular operation; the unit of appropriate H.P. is selected for each operation.

If your manufactures involve the large-scale production of specific components it is worth investigating the possibility of machining them on an Asquith Unit Head machine.

Write to Drummond-Asquith (Sales) Ltd. giving full details of the component and output required.

WILLIAM ASQUITH LTD.

HALIFAX . ENGLAND

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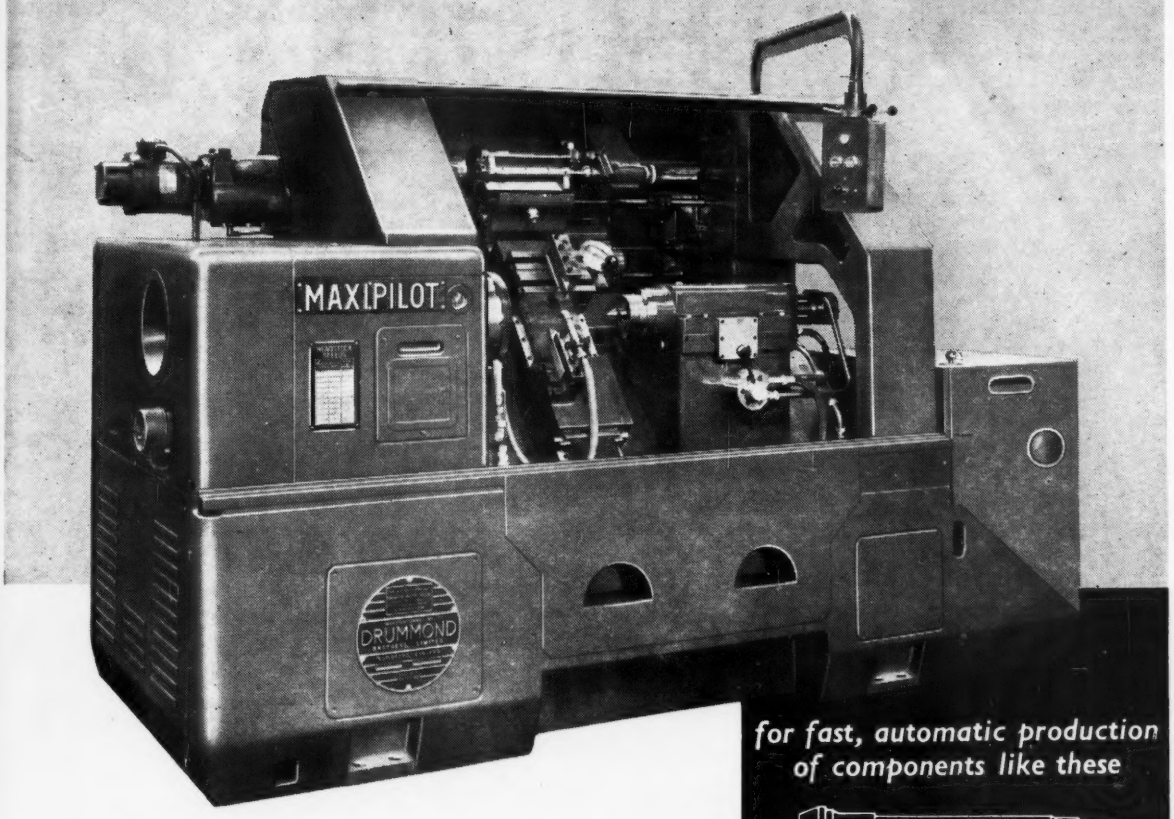
A. 27

Introducing the MAXIPILOT



AUTOMATIC MULTI-CYCLING HYDRAULIC COPYING LATHE

THE MAXIPILOT is an exceptionally rigid and powerful machine designed to exploit to the maximum the cutting possibilities of carbide tools. Round or composite masters are held between centres at the top of the machine clear of swarf and coolant. The template carrier can be automatically indexed by power drive and an eight position longitudinal stop bar rotates with the master and brings in the correct stop for the ensuing machining pass.

The "Maxipilot" is made in two sizes with 20" or 32" between centres and maximum swing of 16" over the bed and 9½" over the cross slide.

Write today for fully descriptive catalogue.

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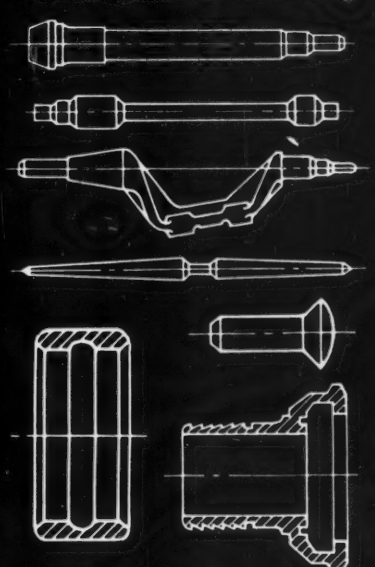
for fast, automatic production of components like these



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Hi-Ton "B" Type 2-ton Bench Press.

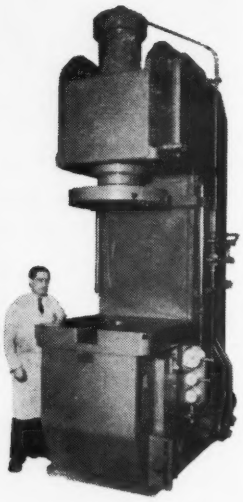
HI-TON

The modern
HYDRAULIC PRESS

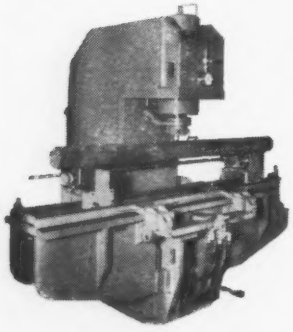
for a wide variety of applications from 1 ton up to 300 tons capacity

All Hi-Ton Hydraulic Presses are designed to give any required pressure from zero to the maximum of the press, the pressure being predeterminable by an adjustable pressure control valve. All types are entirely self-contained and in the case of the presses from 2 tons upwards, the upper half of the body forms the oil reservoir and houses the pump which is completely immersed in this sump. These presses are operated by a light, sensitive foot control lever (hand control is optional), a gate being fitted for cases where it is necessary to maintain full pressure for short periods. A direct reading pressure gauge graduated in tons on the ram indicates the pressure being applied to the work.

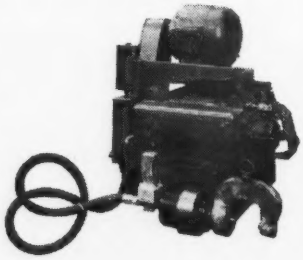
Write to-day for details of Hi-Ton Presses and mention the type of presswork application in which you are interested.



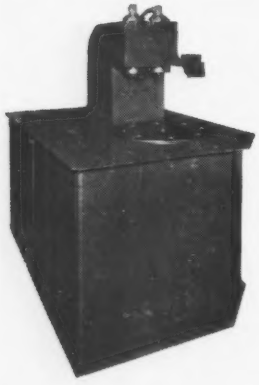
Hi-Ton 150-ton Open Throat Drawing Press.



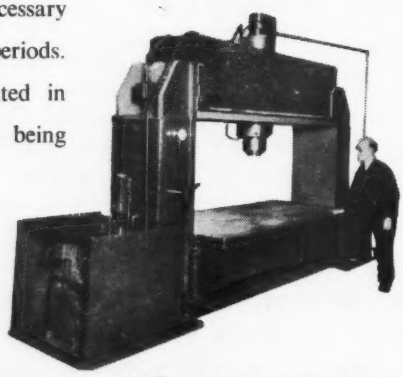
Hi-Ton 75-ton Press equipped with hydraulically operated loading equipment enabling bars to be loaded onto the straightening equipment outside the throat area of the machine.



Hi-Ton HTR.20 Riveting Unit consisting of pump unit and cylinder assembly.



Hi-Ton Indexing Table Machine with two down stroking rams each of 15 tons capacity.



Hi-Ton 100-ton Planishing Press.

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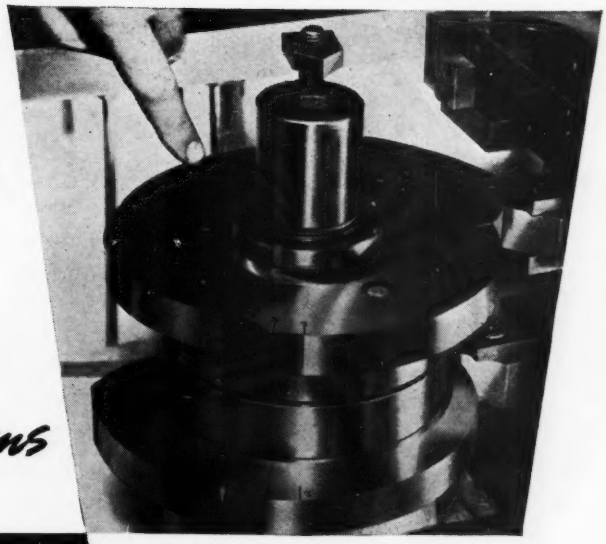
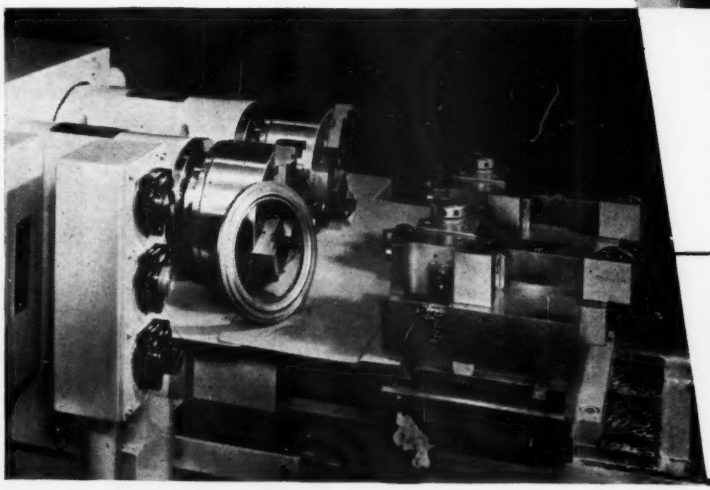
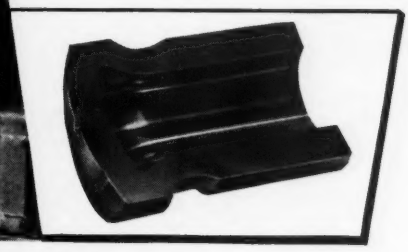
The Simple Approach to **CONTOUR FACING** *and* **BORING** *problems*





CAMS *PUT THE* **PRECISION** *INTO PRECISION BORING!*



NEW BRITAIN MODEL 36 CAM NEWMATIC PRECISION CONTOUR BORING MACHINE

When working to "tenths" cams are the best method of maintaining accuracy, because cam control of the tool is *positive* control. The accuracy of parts produced on New Britain boring machines can't be affected by variable hydraulic pressures, ambient temperature, or play in complicated linkages.

With positive cam actuation in one direction and an air cylinder opposing, the cam provides positive control throughout the operating cycle. A single point tool performs all straight boring and turning as well as generating contours. Work and tools can be mounted on the table or in the spindle.

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THE NEW BRITAIN MACHINE CO. Precision Boring Machine NB

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OPTICAL DIVIDING HEAD

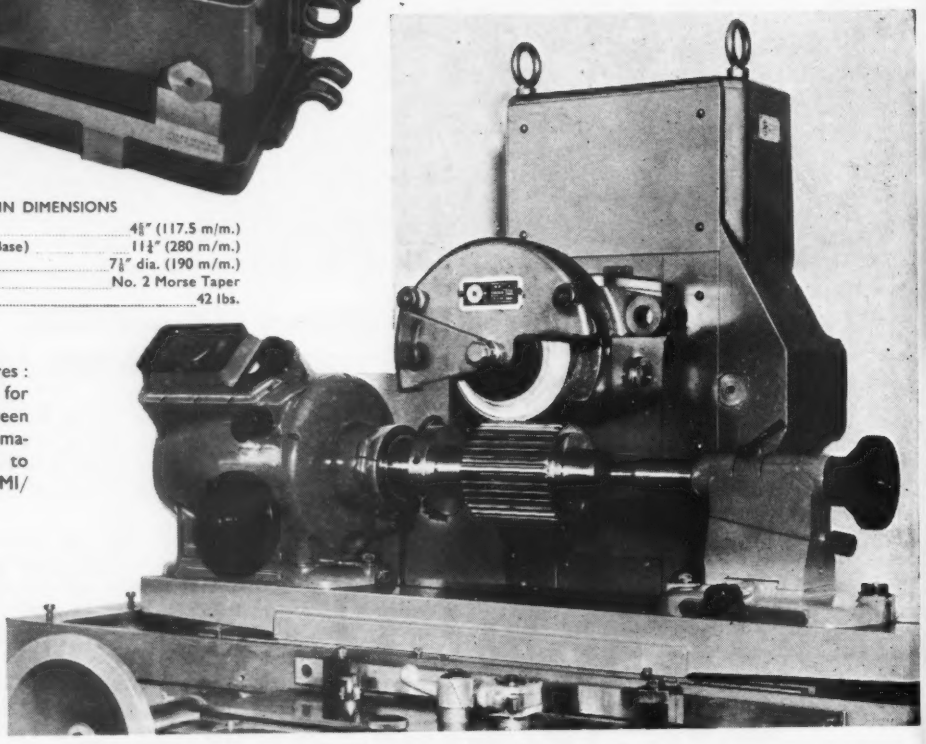
O.D.H. MOUNTED ON SINE TABLE

COMBINING HIGHEST PRECISION WITH ROBUST CONSTRUCTION

MAIN DIMENSIONS

Height of Centres	4⅝" (117.5 m/m.)
Centre Distance (on Base)	11¼" (280 m/m.)
Size of Face Plates	7⅜" dia. (190 m/m.)
Size of Centres	No. 2 Morse Taper
WEIGHT OF HEAD	42 lbs.

Combining the following features: Dead centre, adjustable drive for zero settings, large vernier screen reading direct to 6 secs. (estimation 3 secs.) and conforms to N.P.L. Specification MOY/SCMI/56. Patent 599708.



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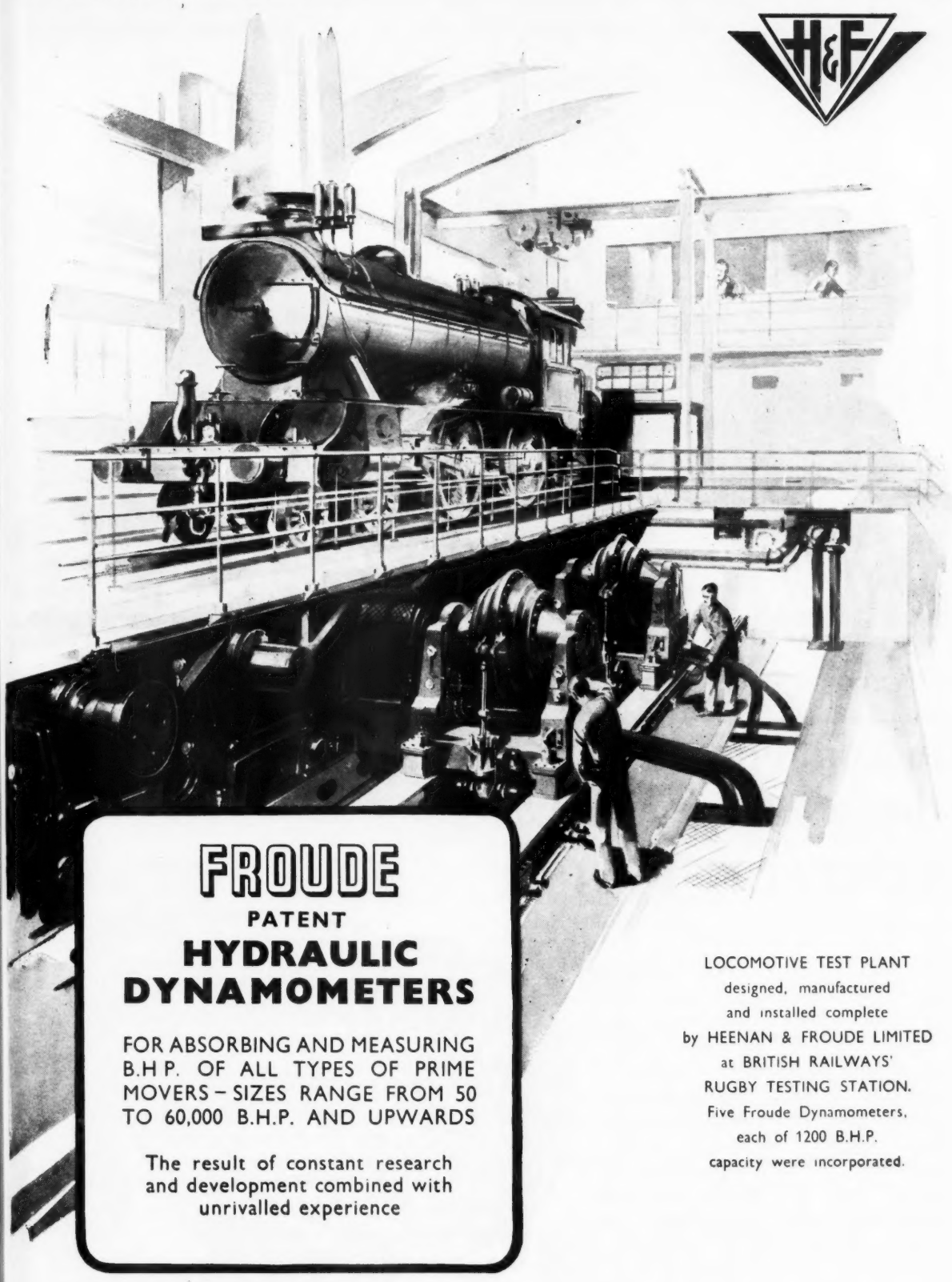

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The result of constant research and development combined with unrivalled experience

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designed, manufactured
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at BRITISH RAILWAYS'
RUGBY TESTING STATION.
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each of 1200 B.H.P.
capacity were incorporated.

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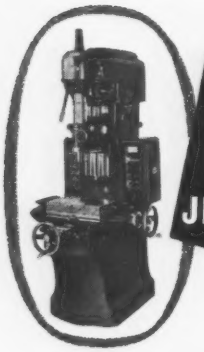

and the MOORE CATMUR JIG Borer

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the ultimate in

JIG GRINDING

We proudly present the first British built Moore-Catmur Jig Grinder. This fine machine cuts time by 25%, accurately locating and grinding holes and contours.

Fast accurate grinding of any contour, regular or irregular, is simple with the Moore-Catmur Jig Grinder. Particularly valuable for form grinding of die sections.

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Supplied with infinite range of grinding speeds from 12,000 to 60,000 r.p.m. Table area 10" × 19".

BRITISH MADE

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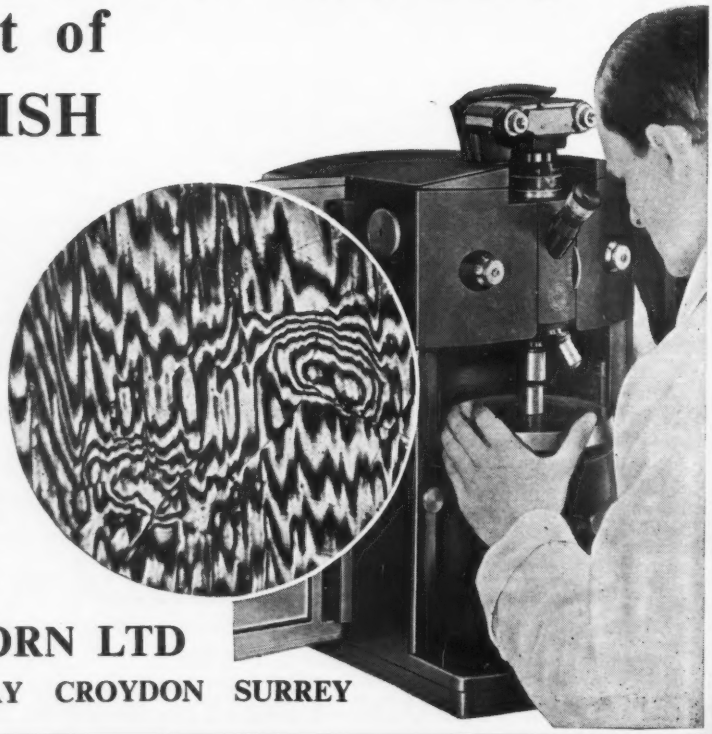
Rainbow

introducing an industrial microscope for the measurement of SURFACE FINISH



The Baker Surface Finish Microscope enables the research or production engineer to see the surface under examination magnified in *three* dimensions: the normal linear magnification of a microscope *plus* the heights and depths of surface contour mapped out by the interference fringes to an accuracy of one micro-inch. The inset shows turned aluminium alloy with grooves and areas where the metal has chipped out.

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Carburising – A great basic advance –

Positive Instrument control of carbon

A CONTINUOUS instrument record of the percent carbon in a furnace carburising gas is now available to you as easily as a temperature record. It shows the percent of active carbon in the atmosphere of the L. & N. Homocarb furnace, and therefore the surface carbon content of the parts being treated. And further, the actual percent carbon is entirely under your control—the carbon you get is the carbon you set on your Microcarb control instrument.

This carbon control unit is of major importance in that it results in a tremendous increase in the versatility of our world-renowned Homocarb electric gas carburising furnace. In addition to its original function of case carburising it can now be used for carbon restoration and homogeneous carburising. In carburising, for instance, excess carbides can be prevented; networks and retained Austenite can be eliminated, thus reducing rejects and lengthening the life of the product. Carbon restoration and homogeneous carburising, previously difficult or impossible to control on production work, are now thoroughly practicable.

Consideration of the above facts will suggest to you that its vastly increased versatility makes the Homocarb furnace an almost indispensable item of Heat Treatment equipment.

Our Technical Staff are at your disposal to suit your convenience. Meanwhile, literature from Dept. M.M.

Heat Treatment
Furnaces for
Carburising
Steam or Air
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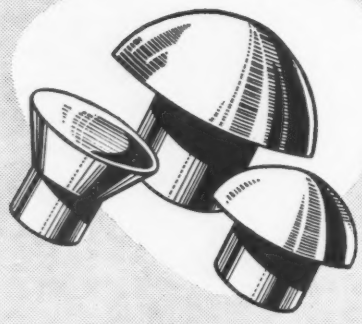
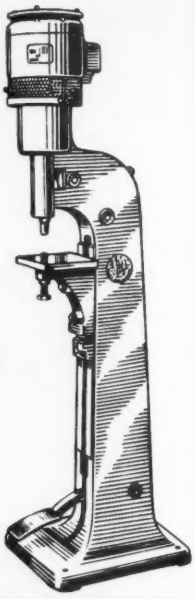


Do you make kitchen equipment, electrical and cycle components, door or window furniture, hand tools? If so, you need T.T. Rivet Spinners. Not only are they faster and cheaper to operate, they enhance the final appearance and form a perfect head without swelling the rivet shank. Coping with mild steel rivets up to ¾in. dia., the range includes vertical single spindle Machines suitable for most purposes, and horizontal duplex models for heading both ends in one operation. Your samples completed for approval.



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TT RIVET SPINNING MACHINES

Illustrated: RS5 VMD ¼in. cap. foot operated. model.

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MACHINE TOOLS LTD
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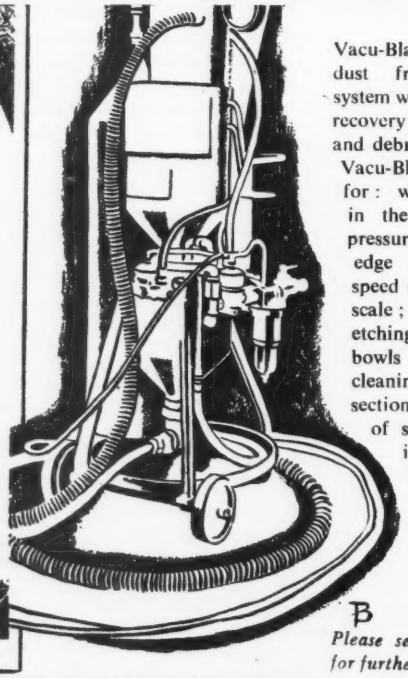
Only VACU-BLAST can do this Job



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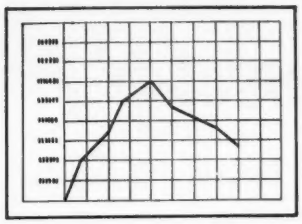

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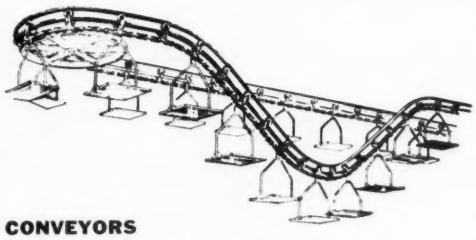
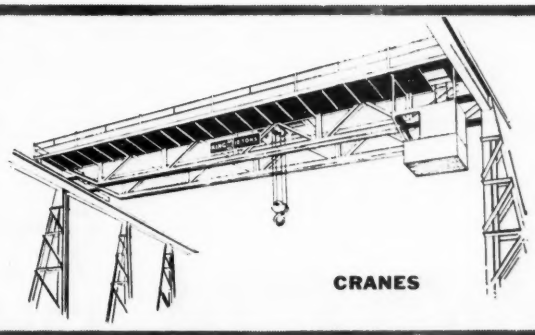


CONVEYORS



CRANES

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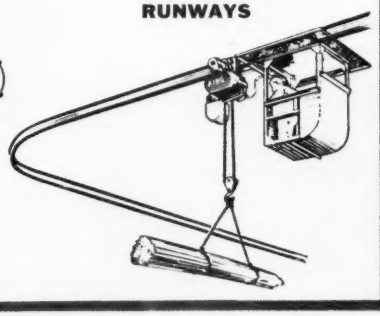

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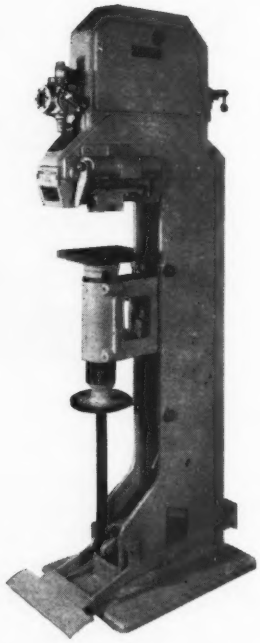
may we present

OUR LATEST E.P. 34 A AIR-OPERATED MARKING MACHINE



This machine, the latest addition to the PRYOR range of marking equipment, simplifies and speeds up the marking of an extremely wide range of cylindrical and flat components. Air operation ensures exact uniformity of impression and reduces operator fatigue to a minimum. A full range of type holders, and geared roller-die carriers is available. Full details of this machine and of our hand-operated models will be sent on request.

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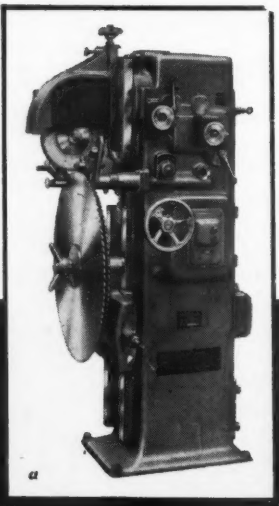


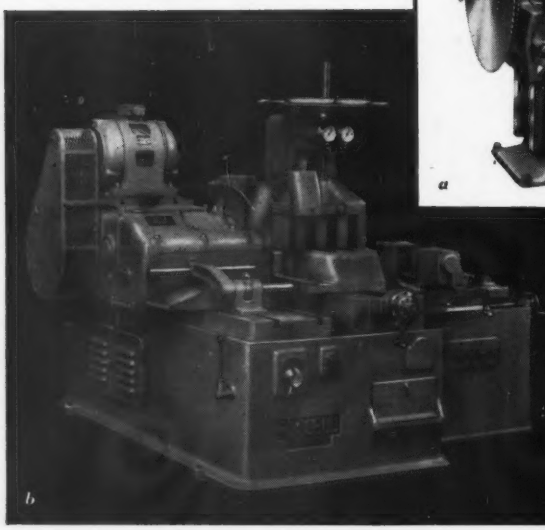
a

The Russell Hydrofeed range includes :

• Straight and angular cutting models • Automatics • Verticals • Special Billet cutting models

Patented Features :

• Interlocking Vices — for easier setting • Hydraulic Circuit — for efficient cutting



b

a **SAW SHARPENING MACHINE** *Capacity 11″ to 48″ blades*

b **'HYDROFEED' COLD SAWING MACHINE** *Automatic bar feed*

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When you're dreaming up plans to increase production it's time to wake up to AZOFLEX. It's the *only* process to apply a controlled quantity of developer, thus ensuring optimum quality at all running speeds—and it's the only daylight reflex copying process. There are no dangerous chemicals and because no ducting is necessary to take away offensive fumes, machines are freely movable from place to place. Exposing, developing and print delivery are completely synchronised and output is virtually as fast as the operator. In plain language the AZOFLEX MODEL 42/63 can produce more than one hundred 20″ × 30″ prints an hour at a lower cost per print than you ever dreamed.

AZOFLEX MODEL 42/63 MARK II

Synchronised printing and developing machine. Capacity: cut sheets and rolls up to 42 in. wide. Printing speed: from 6 in. to 15½ ft. per minute. Dimensions: Height 50 in., width 71 in., depth 52 in. with delivery tray extended. Weight: approximately 850 lb.

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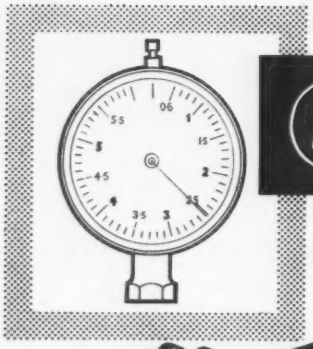

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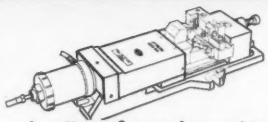
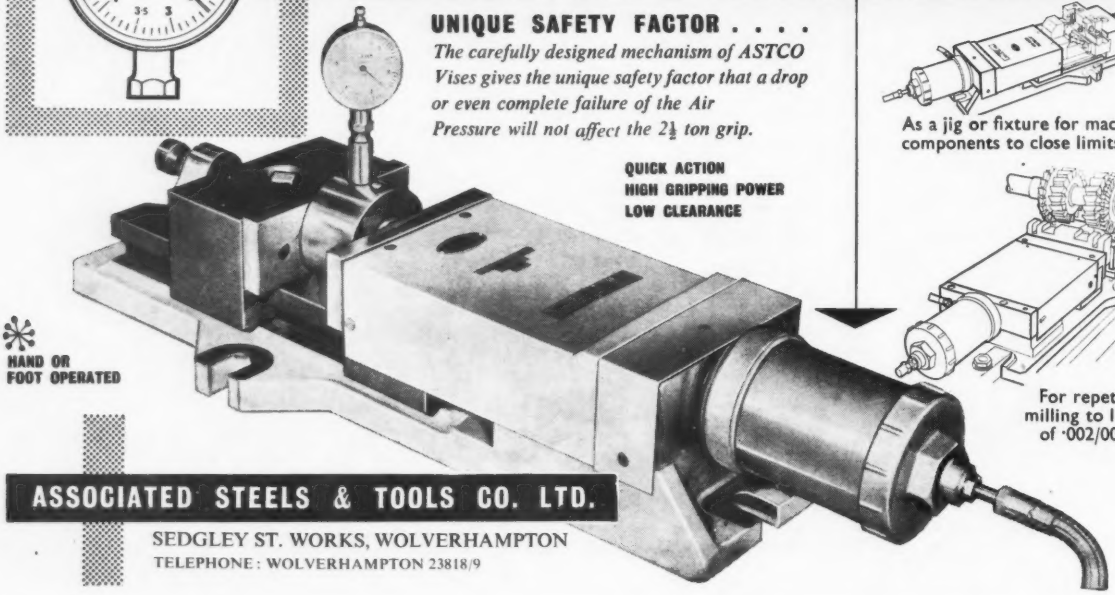
UNIQUE SAFETY FACTOR . . . .
The carefully designed mechanism of ASTCO Vises gives the unique safety factor that a drop or even complete failure of the Air Pressure will not affect the 2½ ton grip.

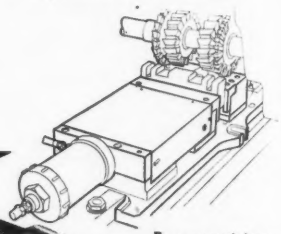


As a jig or fixture for machining components to close limits.

QUICK ACTION
HIGH GRIPPING POWER
LOW CLEARANCE



HAND OR FOOT OPERATED



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REVERSING CONTACTOR UNIT for RATINGS UP TO 10 H.P.
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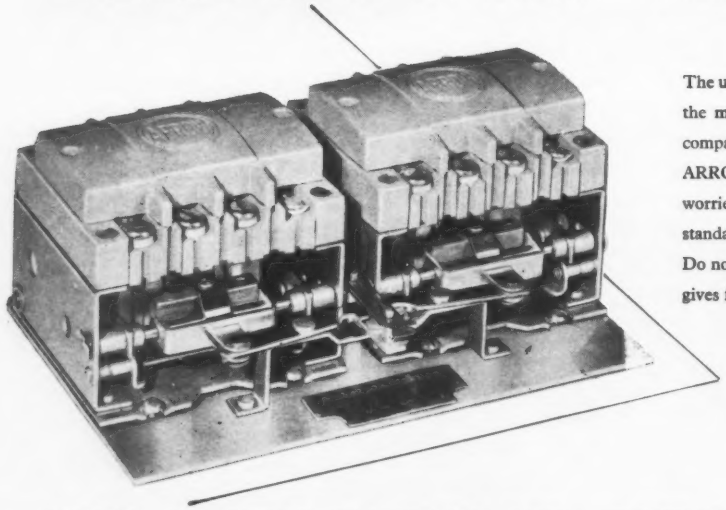
INDIVIDUAL CONTACTOR RATING — 30 amps per pole at 550v A.C. for non-reactive currents



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A.10

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2nd May, 57

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Messrs. Glostics Ltd.,
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For the attention of Mr. A.D.P. Tallents.

Dear Sirs,

In January 1955 you supplied us with two shot blast nozzles in Carbon Tetra Boride. These were immediately put into use in the shot blast cabinets in our Heat Treatment department, working at an air pressure of 40 to 60 lbs/sq. in., and using 30 mesh angular chilled cast iron grit as the abrasive.

It is estimated that each nozzle has now been in service for more than 5,000 hours, and recent dimensional checks show that the amount of wear to be almost negligible. We are advised by you that the original nozzle bore diameter was ⅜", and it will be seen from the following figures that little, if any, wear has taken place.

Bore Size at Throat of Nozzle .3745" to .3742"
Bore Size 1" from Throat .3650" to .3648"

We feel that an outstanding performance such as this should not go unnoticed, and you are therefore at liberty to use the information contained in this letter in any way you wish to further the publicising of C.T.B. nozzles.

Yours faithfully,
for FODENS LIMITED.

E.J. PHIPPS,
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This connection with whomever with any other company making commercial vehicles.

C.T.B SHOT BLAST NOZZLES

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DO NOT FORGET THAT WE HAVE

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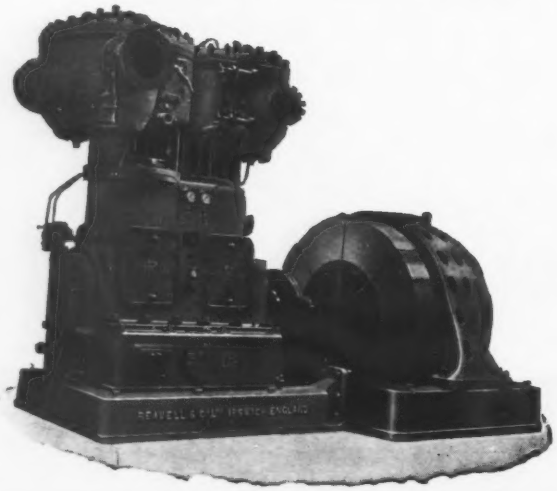

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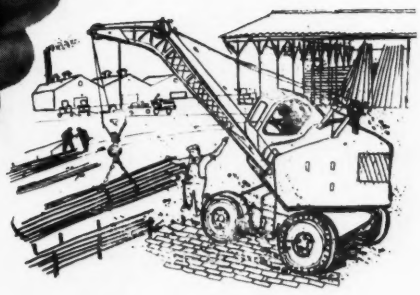

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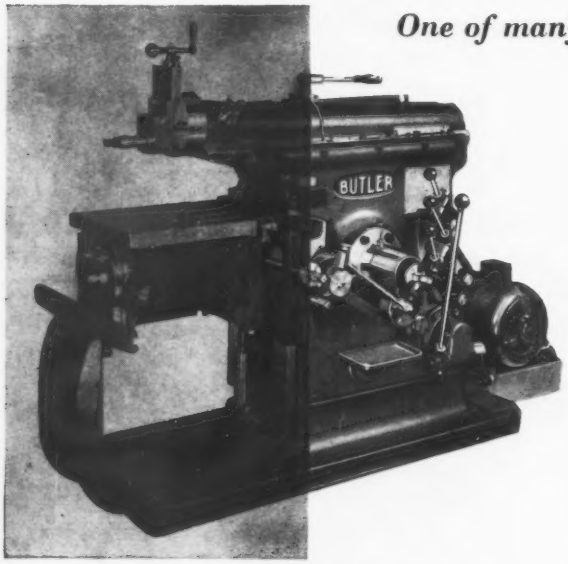

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Mk III Model

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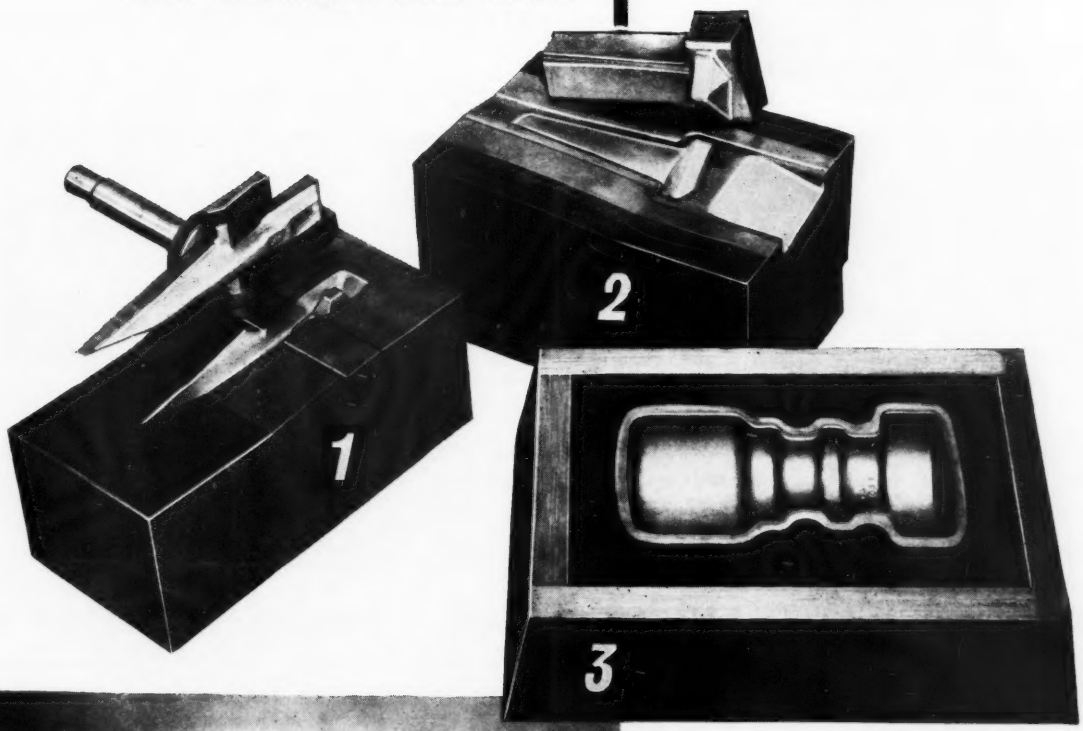

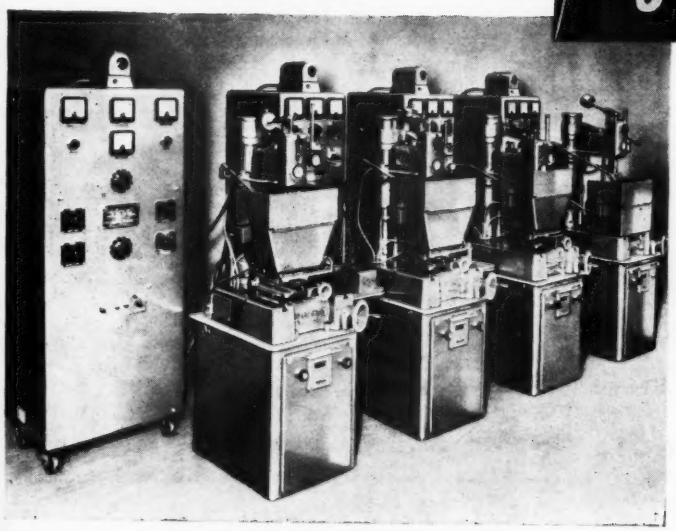

A battery of four Sparcatron heads operated from one main control unit in conjunction with three auxiliary control units.

1 Harvester Tine forging die machined from the solid by Spark Machining in the hardened state

2 Jet Compressor Blade Forging Die reconditioned by Spark Machining

3 Layshaft Forging Die, preformed and finished by Spark Machining

SPARCATRON

Manufactured by

IMPREGNATED DIAMOND PRODUCTS LIMITED
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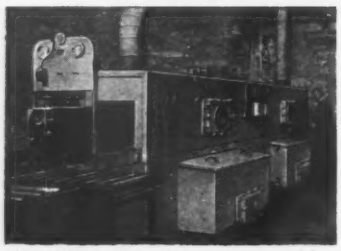
Bratby

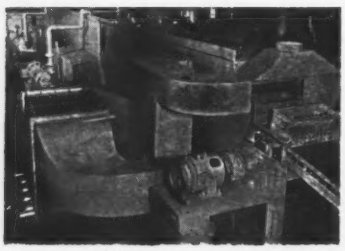
HERE ARE THREE EXAMPLES

INDUSTRIAL CLEANING MACHINES

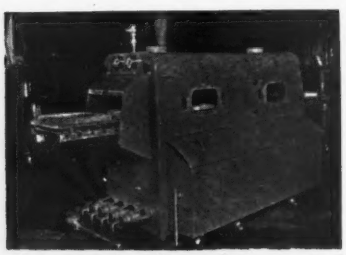
can be designed to meet your particular cleaning problems



This illustration shows a machine cleaning crank cases in the production line. It is equally capable of cleaning small parts in baskets.



A power driven conveyor system is employed with this cleaning machine for ball bearings.



Trays carrying the work are pushed through on a roller conveyor by hand in this cleaning installation.

Whilst offering a very wide variety of standard cleaning equipment, it is BRATBY policy, wherever possible to design the machine to meet the particular cleaning problem. Careful study of each individual problem ensures maximum efficiency and economy of the plant in operation. The illustrations show but a few of the specific types of Cleaning Machines designed by BRATBY for individual needs.

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PATENT CALIPER GAUGE MODEL 52

Each month one of the seven main advantages of this fine precision instrument will be described.

- Many different gauging positions can be obtained.
- The anvils are set so that they do not roll.
- ★ All shearing action is eliminated.

  Particularly suitable for gauging shouldered work.
- Can be used for either left or right hand threads.
- Particularly suitable for the gauging of acme forms of thread.
- Can be supplied for "GO" only, or "NOT GO" only, or both "GO" & "NOT GO" combined.

NOTE THIS MONTH'S IMPORTANT FEATURE

★

ALL SHEARING ACTION IS ELIMINATED

As the anvils are radial all shearing action is eliminated. This is a particularly advantageous feature, especially when soft metals are being gauged.

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Chairman of ROOTES GROUP writes:—

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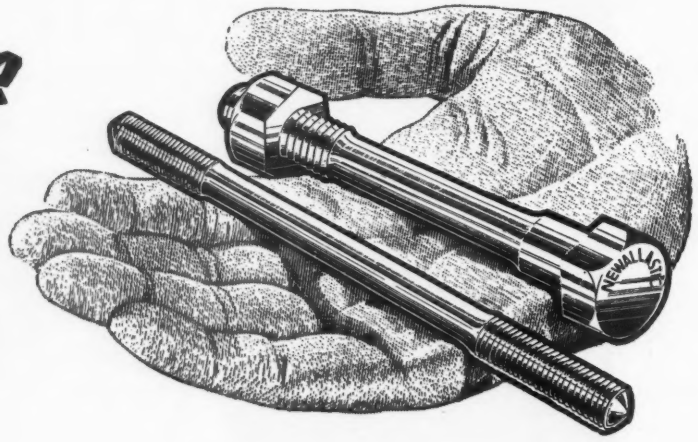
"Newallastic" bolts and studs have qualities which are absolutely unique. They have been tested by every known device, and have been proved to be stronger and more resistant to fatigue than bolts or studs made by the usual method.



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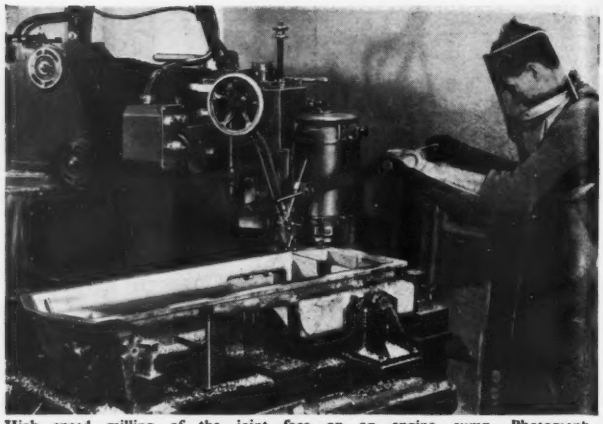
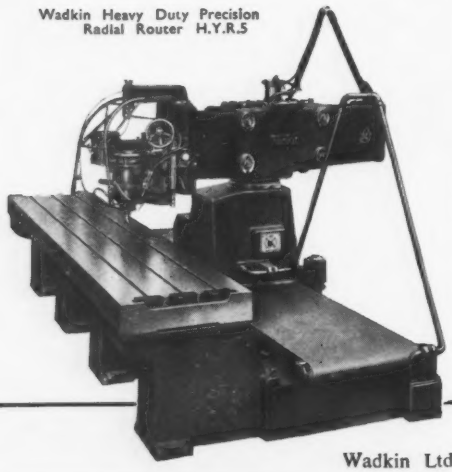
Revolutionising machining times on NON-FERROUS METALS



High speed milling of the joint face on an engine sump. Photograph by courtesy of Messrs. Rolls-Royce Ltd., Oil Engine Division, Derby.

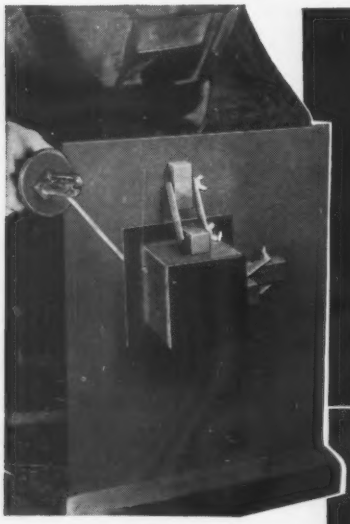
Wadkin Heavy Duty Precision Radial Router H.Y.R.5



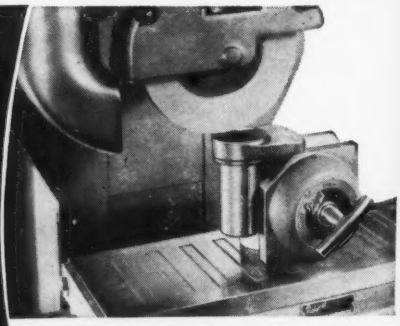
The new high speed milling techniques developed by Wadkin guarantee light alloy components being machined in the fastest possible times. Unlike conventional machine tools, Wadkin employ cutting speeds up to 18,000 r.p.m. This ensures remarkably free cutting, an extremely fine finish, and a metal removal rate of 20 cu. ins. per minute. It's a performance that, in some instances, has cut down production times by more than 80%. If you are face milling, pocketing or profiling non-ferrous castings or sheets it would pay you to investigate.

Telephone: Leicester 67114 **Wadkin** *Telephone: MAYfair 7048-9*

Wadkin Ltd., Green Lane Works, Leicester. London Office: 62 Brook St., London W.1



Permagic multiplies your hands



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Use these magnetic tools and release labour for other, more productive work.

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Write for booklet "Magnetic Aids to Speed Production"

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Supplies through appointed "Eclipse" Distributors

PM 134

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WIDE SPEED RANGE
and VERSATILITY
Archdale
38" SENSITIVES
Here is the baby of the range, showing its paces on a nickel chrome steel cylinder head. The International Harvester Co. Ltd., of Doncaster, find the spot facing and tapping of 8" × ½" diameter holes reduced to child's play on the ARCHDALE 38". Jobs of this sort show the ease and speed of operation of these handy little machines to good advantage.
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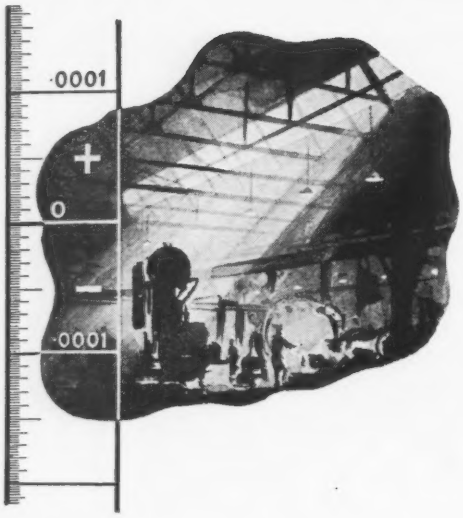

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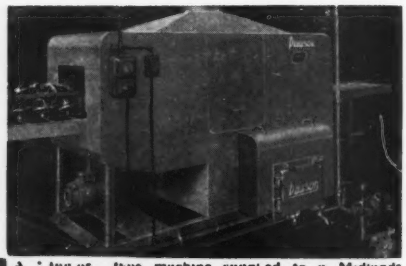
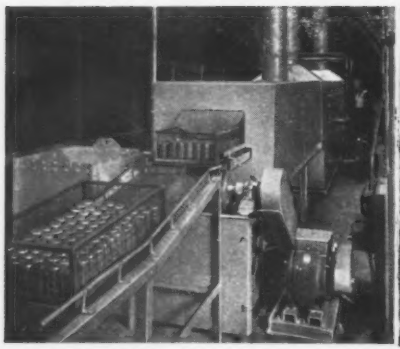


A 'Junior' type machine supplied to a Midlands Motor Car Works.



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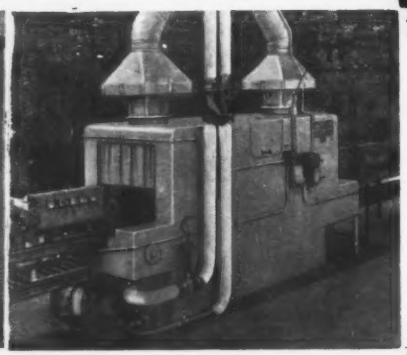

A model 'A' machine washing parts of motor car engines prior to assembly.

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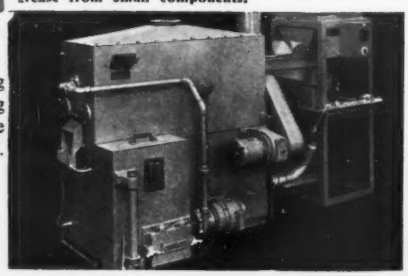

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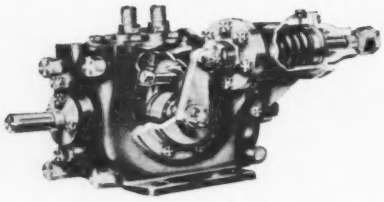

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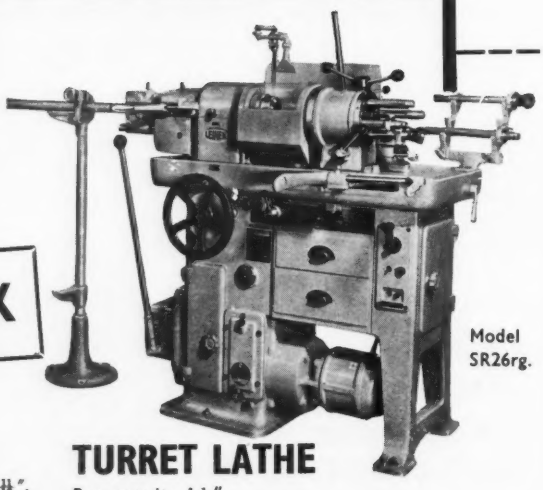

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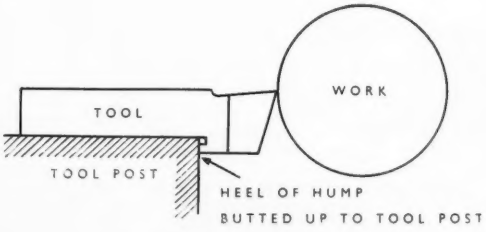

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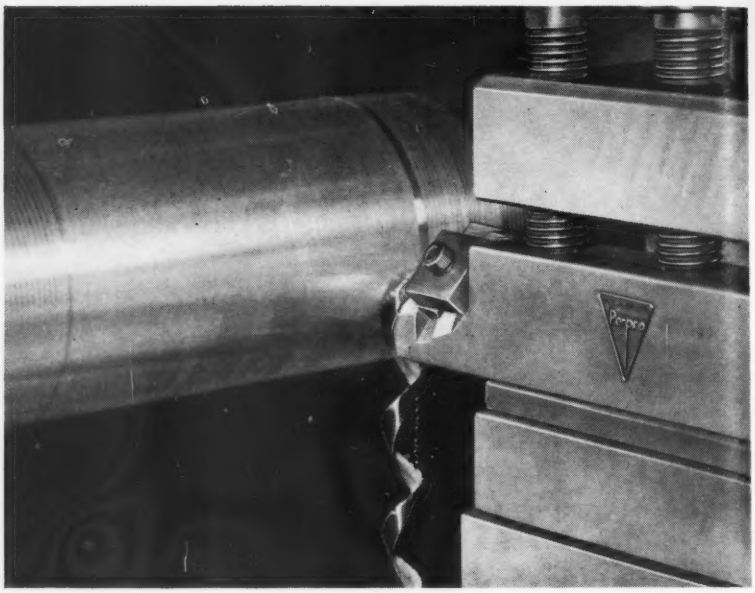
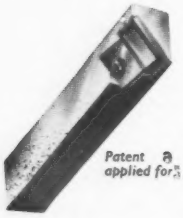


Cross Cross tool cutting S.96, 80-ton steel at 600 ft./min. Depth of cut 0.035 in., feed 0.06 in./rev. By permission of the College of Aeronautics.



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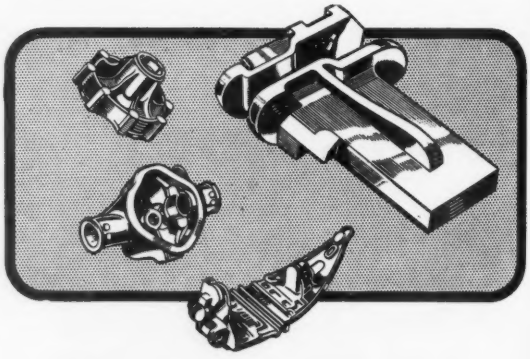

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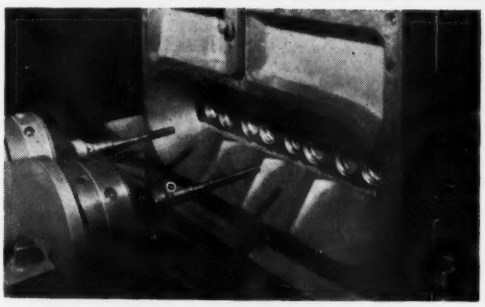

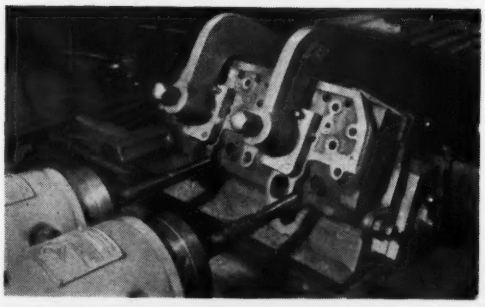

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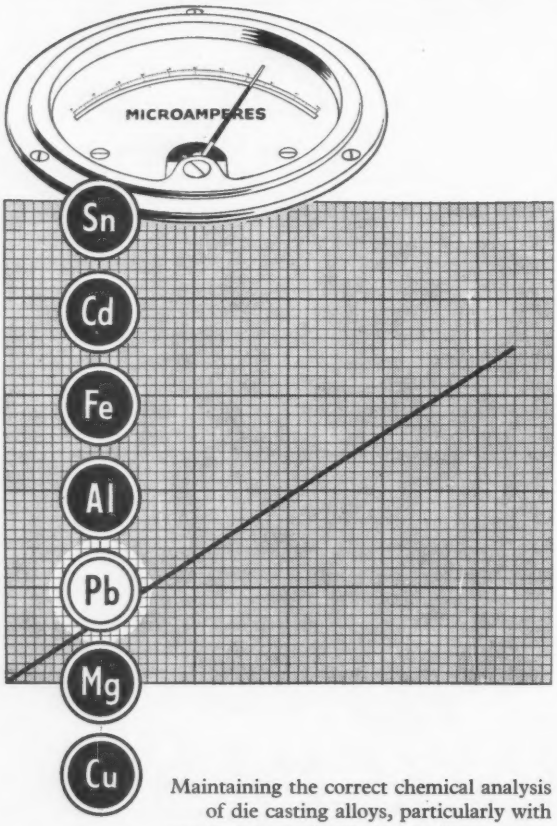

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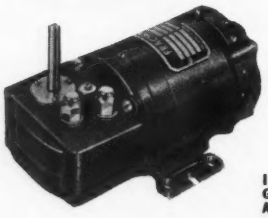

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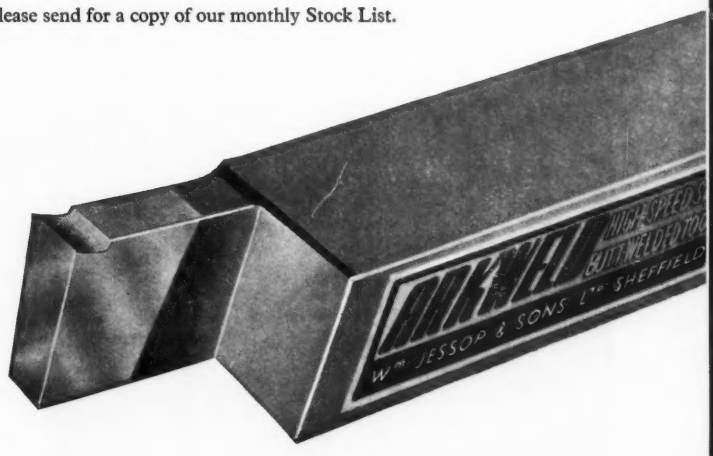

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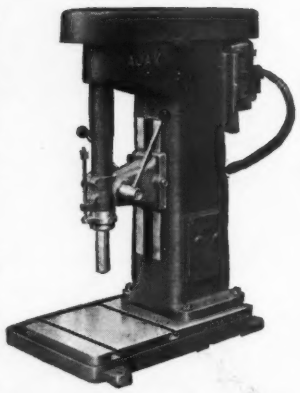

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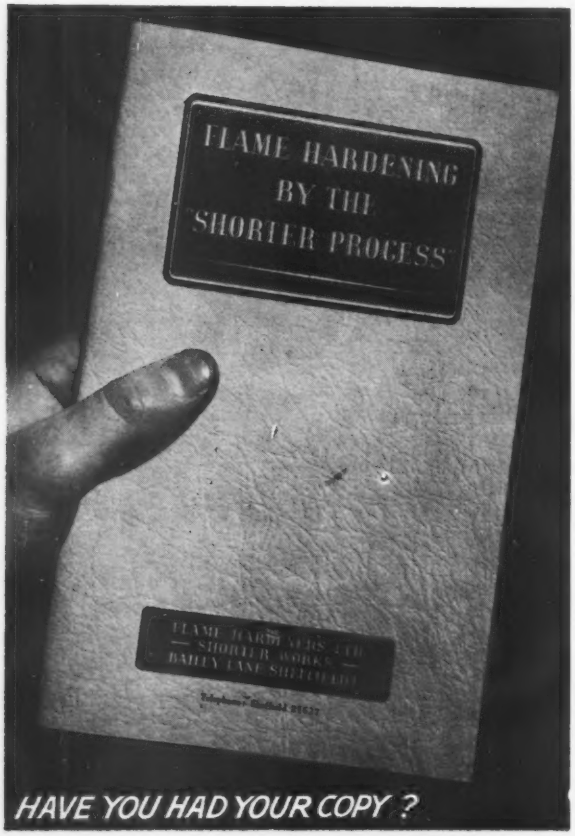

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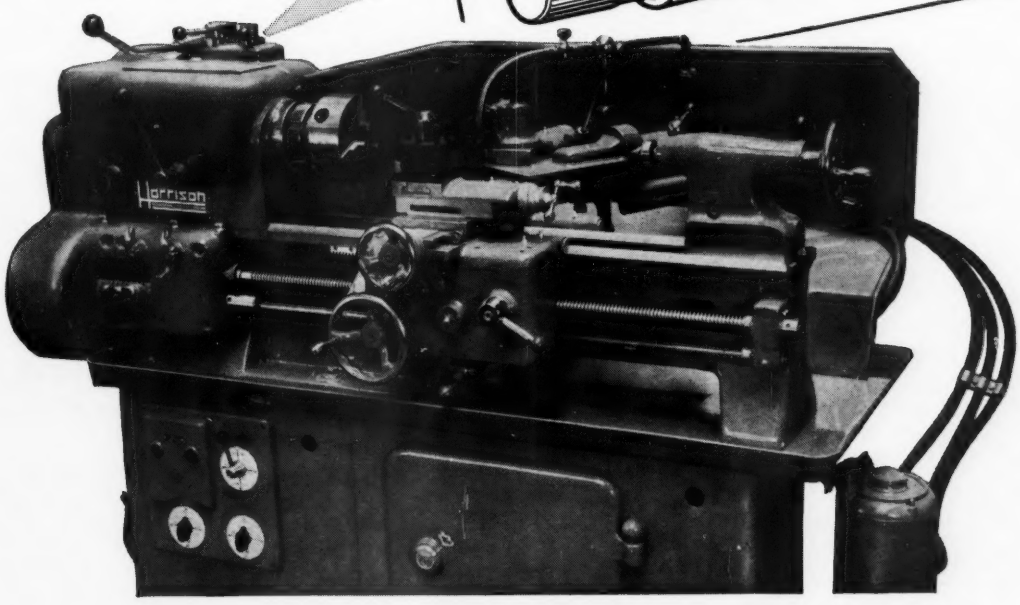

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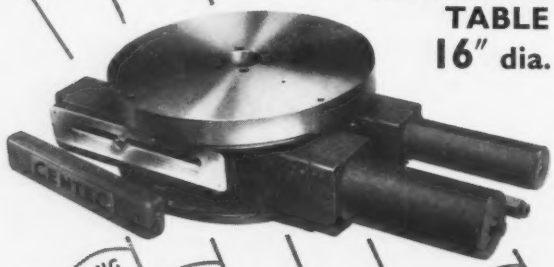

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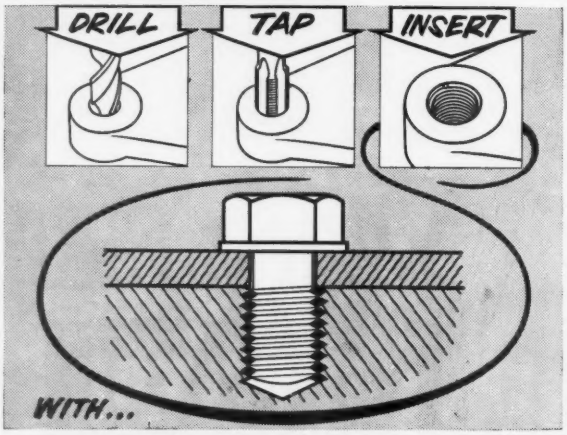

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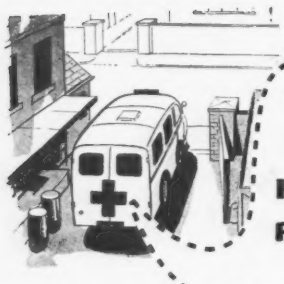

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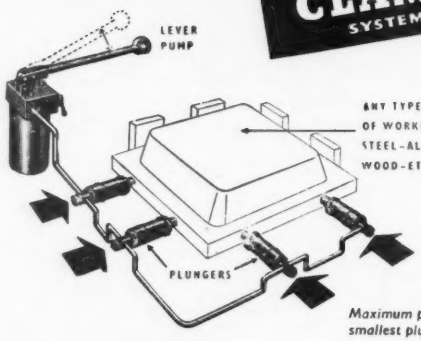

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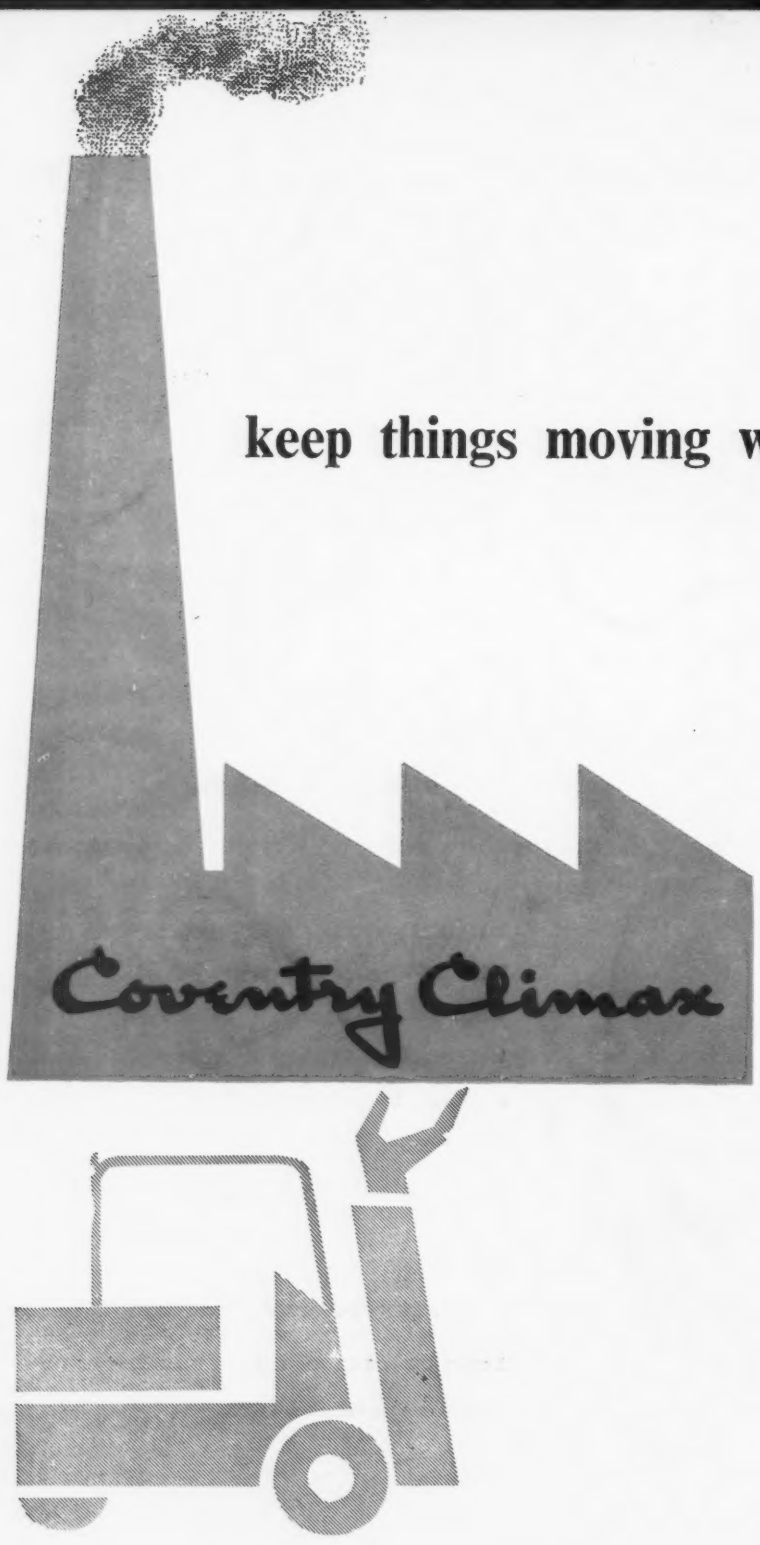

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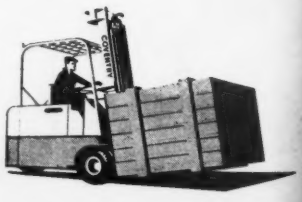

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